

PSYCHOLOGICAL AND PHYSIOLOGICAL CONTRIBUTORS TO CARDIOVASCULAR  
HEALTH IN REGULAR PRACTITIONERS OF YOGA

by

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## **Abstract**

The evidence of the cardiovascular benefits of yoga is promising, but is limited by a lack of examination of mechanisms and specificity of effects compared to other interventions. To address these weaknesses, the present cross-sectional study comprehensively examined psychological and physiological contributors to cardiovascular health in regular yoga practitioners compared to regular runners and to sedentary individuals. Blood pressure (BP), heart rate (HR), and high frequency power (HF), a measure of heart rate variability, were measured at rest, and changes in BP and HR were measured in response to two laboratory stressors: an isometric handgrip task and a mental arithmetic task. Potential mediators of group differences on these outcome variables were measured including psychological factors, lifestyle factors, respiration rate, waist circumference, and aerobic fitness. In the present study, yoga practitioners and runners, relative to sedentary individuals, had significantly lower resting HR, higher HF, fewer depressive and anxious symptoms, lower hostility, less incidence of cigarette smoking, and superior aerobic fitness levels. Yoga practitioners had a higher rate of vegetarianism compared to runners and sedentary individuals. Yoga practitioners who reported regularly practicing a breathing technique called Ujjayi had a significantly lower respiration rate compared to runners and sedentary individuals. The lower resting HR in yoga practitioners compared to sedentary individuals was partially mediated by aerobic fitness, and the relatively higher HF power was partially mediated by both aerobic fitness and respiration. Implications and suggestions for future research are discussed.

## **Preface**

No part of the research presented in this document has been published. The study presented in the dissertation was approved by the UBC Behavioural Research Ethics Board, certificate number H09-02442.

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## **Dedication**

This work is dedicated to those who commit to improving their own health, and to those who commit to improving the health of others.

# **1 Introduction**

## **1.1 Yoga in North America**

In the most comprehensive assessment of Canadians' use of complementary and alternative medicine (CAM) to date, 76% of Canadians endorsed the attitude that "Conventional medicine does not have all the answers to our health problems" (Esmail, 2007, p. 30).

Consequently, nearly three-quarters (74%) of Canadians reported using CAM therapies in their lifetimes. Out of over 20 CAM therapies, yoga was reported as the most likely to be used to prevent future illness or to maintain health. Sixteen percent of Canadians reported practicing yoga at some point. The lifetime prevalence of yoga use was highest in British Columbia at 20%, and 57% of those individuals had participated in yoga in the last year.

In a survey of opinions of professional organizations in the United States, yoga centre owners asserted that they could treat anxiety/perceived stress, headaches/migraine, back pain, insomnia, cardiovascular problems including high blood pressure, circulatory problems, musculoskeletal problems, menstrual problems, and multiple sclerosis (Long, Huntley, & Ernst, 2001). Perhaps no other practice has been implicated in the treatment of such numerous and varied health problems as yoga. Yoga has also been reported to be effective in treating bronchial asthma, mucous colitis, peptic ulcer, cervical spondylosis, chronic sinusitis, intractable pain, personality disorders, depression, gastritis, and rheumatism (Singh, 2005). Specific Kundalini yoga techniques have been described for phobias, addictions, depression, grief, sleep disorders and dyslexia (Shannahoff-Khalsa, 2004). Locally, mental health professionals in Vancouver and the Lower Mainland, British Columbia have demonstrated their convictions, or at least openness,

that yoga can aid in the treatment of mental illness by offering yoga in mental health wards (e.g., Brief Intervention Unit at Vancouver General Hospital, Burnaby Mental Health and Addictions).

The present study focuses on the potential benefits of yoga on psychological and physiological variables that predict cardiovascular health, by examining regular yoga practitioners, known as yogis. With the vast list of health problems allegedly alleviated by yoga, cardiovascular health was chosen as the health outcome of interest for several reasons. Firstly, cardiovascular disease is the second most prevalent cause of death in Canada after cancer, accounting for over 27% of deaths in Canada (Statistics Canada, 2007). Secondly, there is a considerable body of literature that largely supports the effectiveness of yoga in promoting cardiovascular health, albeit one that is fraught with methodological weaknesses (Innes, Bourguignon, & Taylor, 2005). Lastly, because yoga, including the physical practice of *asana* (postures), may influence both physiological and psychological components that have been theoretically linked with cardiovascular health, an exciting opportunity exists to develop theory to explain how it is that yoga could exert beneficial cardiovascular effects.

This study aims to examine these physiological and psychological variables in regular practitioners of yoga, and to compare these variables with regular runners, and with participants who have no regular health promoting practice. This design is meant to highlight the specificity of potential differences between individuals who practice yoga and those who do not. Sixty-seven percent of Canadians endorse the statement: “Just because alternative medicine hasn’t been scientifically tested and approved by Canadian and provincial medical bodies doesn’t mean it isn’t effective” (Esmail, 2007, p. 30). Despite this, I believe that the scientific study of yoga is essential in determining the appropriate role of yoga within the conventional medical

system, in informing the public, and in providing health care professionals with the knowledge to make informed recommendations.

## 1.2 What is yoga?

The term ‘yoga’ is shrouded in mystery due to its long history, varied practices and philosophical depth. Because there is no one definitive source on yoga, it is a difficult topic for Western scientists to study. The word ‘yoga’, classically translated as ‘to be one with the divine’, has many translations from Sanskrit to English. Common translations are ‘to yolk’ and ‘to unite’, while more elaborate translations are ‘to tie the strands of the mind together’ and ‘to attain what was previously unattainable’ (Desikachar, 1995). Yoga has its origins in the *Vedas*, which is the first written record of Indian culture. Although under considerable debate, the Vedas have been traced as far back as 7000 years, beginning as oral tradition. Yoga is one of the six fundamental systems of Indian thought collectively known as *Darśana*, translated as ‘point of view’ or ‘a certain way of seeing’ (Desikachar, 1995).

There are different kinds of yoga branches that need not be mutually exclusive, including: *Raja* yoga (classical yoga; eight-limbed path), *Bhakti* yoga (path of devotion to the divine, to guru), *Karma* yoga (path of service to others), *Jnana* yoga (path of the scholar), *Tantra* yoga (path of ritual), and *Hatha* yoga (forceful path or path of willpower), which is the branch of yoga typically referred to as ‘yoga’ in North America.

Hatha yoga refers to the practice of asana (physical postures), incorporating *pranayama* (‘control of life force’ or breathing exercises), and meditation, and this is how the term is used in this paper. Confusingly, North Americans often refer to ‘Hatha yoga’ as a particular style of yoga which includes asana, pranayama, and meditation, and tends to be gentle. Hatha yoga is allegedly

traced back to the 1200's, but the oldest surviving text describing asana is the Hatha Yoga Pradipika, compiled by Yogi Swatmarama in the 1400's. Tirumalai Krishnamacharya is credited as the father of the renaissance of Hatha yoga in the 1900's. His disciples went on to create most of the popular types of yoga practiced in North America today including Iyengar yoga (B. K. S. Iyengar), Ashtanga or Vinyasa yoga (Pattabhi Jois), and yoga therapy (T. K. V. Desikachar). It was not until the 1960's that Hatha yoga was popularized in North America by individuals who returned to North America after studying in India.

Practitioners of Hatha yoga are often influenced by the philosophy presented in Classical yoga, or *Raja* yoga. This is noteworthy, because this component of yoga practice may have psychological influences beyond the physical components. Raja yoga was systematized in the Yoga Sutra of Patanjali, which is considered the most significant text on the topic of yoga, and estimated to have been written between 50-200 CE. The book is comprised of 196 *sutras* or short 'threads' of wisdom. The Yoga Sutra defines yoga as the restraint of mental modifications, or the ability to direct the mind without distraction. Eight steps or 'limbs' are described, which build on one another, but are encouraged to be practiced together, including: 1) *Yama* (a list of practices to abstain from), 2) *Niyama* (a list of practice to observe), 3) *Asana* (posture, referring to a seated position), 4) *Pranayama* (breath control), 5) *Pratyahara* (sense withdrawal), 6) *Dharana* (concentration), 7) *Dhyana* (meditation), 8) *Samadhi* (contemplation, absorption or super-conscious state).

It should be noted that the Yoga Sutra neither forces the concept of God on its readers nor rejects it, and this has allowed the text to be universal. The Yoga Sutra is, however, quite esoteric in that there are many possible translations and interpretations, and the content is deeply philosophical and spiritual. For example, the purpose of yoga is described as a journey to



Samadhi, which is a state of total absorption when one's inner observer becomes one with what is being observed. Given the elusive nature of yoga, it is no wonder that yoga's most tangible forms (physical postures and some of the simpler breathing exercises) rather than the more complex concepts have become popularized in North America (Farhi, 2000).

Because the majority of the North American public thinks of yoga primarily as yoga asana, the practice of asana was a minimum requirement for group inclusion in the present study. The study included practitioners of all types of Hatha yoga except for those who practice Bikram yoga or other types of yoga performed in heat, because of the confound of regular exertion in temperatures around 42 degrees Celsius (107.6 degrees Fahrenheit). Other common types of Hatha yoga are similar to each other in that they incorporate many of the same techniques, but one major difference between them is aerobic intensity. According to a coding scheme that classifies physical activity based on energy expenditure, yoga is classified as stretching, with a metabolic equivalent (MET) of 2.5 (Ainsworth et al., 2000). However, when more active asana are included, like the flowing series of postures known as Sun Salutations in Ashtanga or Vinyasa flow yoga, energy expenditure increases to 3.74 (Clay, Lloyd, Walker, Sharp, & Pankey, 2005). By comparison, however, running has a MET of up to 18.0. Because of the differences in intensity between types of Hatha yoga, aerobic fitness was measured. It was not a study aim to make specific statements about types of Hatha yoga, but rather about Hatha yoga practice, on average, in Vancouver at the point in time of the study.

### **1.3 Does yoga improve cardiovascular health?**

Several overlapping systematic reviews have been published on the effects of yoga practice on cardiovascular health (Aljasir, Bryson, & Al-Shehri, 2008; Innes et al., 2005;

Jayasinghe, 2004; Mamtami, 2005; Raub, 2005; Yang, 2007). Studies in these reviews include populations with heart disease or hypertension (Mamtani & Mamtani, 2005; Yang, 2007), both healthy populations and populations with heart disease or hypertension (Innes, 2005; Jayasinghe, 2004; Raub, 2005), and populations with diabetes mellitus (Aljasir et al., 2008). These reviews are consistent in concluding that yoga is potentially protective against cardiovascular disease, but the lack of scientific rigour in many of the reviewed studies makes conclusions tentative.

The most comprehensive of these reviews is Innes' (2005) systematic review of the research on the effect of yoga on risk indices associated with insulin resistance syndrome and cardiovascular disease. The review's account of the descriptive characteristics of included studies gives a representative depiction of available research on this topic, and is therefore elaborated on here. The review included a total of 70 articles published in English between 1970 and 2004. The studies were comprised of one cross-sectional study, seven studies (six controlled) that only examined acute changes over one or two yoga sessions, 25 uncontrolled clinical trials, 15 nonrandomized controlled clinical trials, and 22 randomized controlled trials. Research on the topic of yoga and cardiovascular disease markers has increased over time, with the majority of studies being published after 1990. The majority of studies have been conducted in India. The most common risk indices considered in these studies include, but are not limited to, resting heart rate (HR), SBP and DBP (Innes et al., 2005).

There are many methodological difficulties that obscure interpretation of results. A major difficulty in studying the effects of yoga is that yoga is an elusive concept. Under the umbrella of 'yoga', interventions range considerably. All of the studies described in Innes et al.'s (2005) review examined the effects of yoga, but varied in the emphasis on asana, breathing, meditation, philosophy, and lifestyle. Some interventions involved major lifestyle changes like imposed

vegetarianism or living in a controlled environment away from daily responsibilities, making it impossible to isolate the effects of yoga alone. Even when interventions consisted only of asana, they varied in style and type of postures, and on the relative emphasis on breathing and meditation. The interventions also varied considerably in duration of each session, frequency per week, length of intervention, and time of measurement. For this reason, a meta-analysis on this topic has been unsuitable, which is unfortunate, because even as the body of literature keeps growing, we do not get closer to definitive conclusions. The available studies do not provide the optimal style, duration, or intensity of practice that will maximize the benefits of yoga (Yang, 2007).

Besides difficulties that are inherent to studying yoga, there are methodological flaws that seem to be pervasive in this area of research. Randomized controlled trials are lacking, and even the existing randomized controlled trials are difficult to interpret due to inappropriate control groups. There is a paucity of studies that examine the effects of yoga compared to conventional practice of Western Medicine or other self-regulation methods, and therefore it is difficult to determine the direct benefits of yoga (Mamtani & Mamtani, 2005). Another problem that is common in this literature is small sample sizes. Innes (2005) found that over 40% of studies included in their review had samples of less than 25 participants. Finally, Western populations are underrepresented in the literature, limiting generalizability of findings. Although the methodological limitations in this body of research are numerous, the general picture of the effect of yoga on various indices of cardiovascular health is intriguing. The most commonly studied variables of interest are heart rate (HR), systolic blood pressure (SBP) and diastolic blood pressure (DBP). A brief review of these findings follows.

### **1.3.1 Blood pressure**

Blood pressure (BP) is the most commonly studied cardiovascular index in the yoga literature. Innes et al. (2005) identified a total of 37 studies that measured BP, including one cross-sectional study, 10 uncontrolled studies, 12 nonrandomized controlled trials, and 13 randomized controlled trials. A total of 29 studies out of the total 37 found significant reductions in BP in yogis. Eleven out of the 13 randomized controlled trials reported significant results, including studies that examined the effects of yoga in patients with hypertension or other risk factors of cardiovascular disease and in healthy populations. Even when compared to a heart-healthy diet and exercise group, greater reductions in BP were found in the yoga group (Fields et al., 1989; Harinath et al., 2004). Studies demonstrated declines of up to 24% in DBP, and up to 21% in SBP. Of the total studies reporting positive changes with yoga alone, 10 used active yoga postures, and 10 used only relaxation postures alone or in combination with meditation (Innes et al., 2005).

Since the publication of Innes' review, at least two additional trials of yoga including asana examining BP have been published. In an uncontrolled pilot trial of 6 weeks of yoga asana and meditation, both coronary artery disease (CAD) patients and healthy participants exhibited reductions in BP, without changes in diet, medication, or aerobic exercise (Sivasankaran et al., 2006). Finally, a randomized controlled trial that included adult participants with HIV at risk of cardiovascular disease showed significant reduction in resting SBP and DBP after 22 weeks of two to three weekly Ashtanga Vinyasa yoga sessions compared to standard care (Cade et al., 2010).

### **1.3.2 HR**

Innes et al. (2005) identified 25 studies that examined the effect of yoga practice on resting HR, with 21 reporting significant reductions of up to 38%. Of these, the only randomized controlled trial found that yoga practice reduced HR even when compared to an aerobic exercise program (Bowman, Clayton, Murray, Reed, Subhan, & Ford, 1997). Additionally, a previously described pilot study by Sivasankran et al. (2006) found reductions in HR in both CAD patients and healthy participants.

### **1.3.3 Heart rate variability**

Heart rate variability (HRV) is defined as the change in the time interval between heart beats, or the inter-beat fluctuations in HR (Terathongkum & Pickler, 2004). At rest, healthy individuals show variations in the intervals between their heart beats corresponding with their respiration cycle. HR accelerates during inhalation and decelerates during exhalation. HRV is a measure of the functioning of the autonomic nervous system (ANS), comprised of the sympathetic nervous system (SNS), which increases HR, and the parasympathetic nervous system (PNS), which decreases HR through the vagus nerve.

Low HRV has been associated with a range of negative cardiovascular health outcomes including incidence of coronary heart disease (CHD), poorer prognosis for individuals with CHD or cardiac failure (Dekker et al., 2000; Janszky et al., 2004; Liao et al., 1997), hypertension (Huikuri et al., 1996; Singh et al., 1998), cerebrovascular disease (Kario et al., 1997), diabetic neuropathy (Chessa et al., 2002), congestive heart failure (Bilchick et al., 2002) and fatal arrhythmic complications following acute myocardial infarction (Fei, Copie, Malik, & Camm, 1996).

HRV has not been as frequently studied as BP and HR in yogis. Several studies have demonstrated immediate increases in HRV measured before and after the practice of different yoga components including breathing exercises (Raghuraj, Ramakrishnan, Nagendra, & Telles, 1998), yoga mantra repetition (Bernardi et al., 2001) and a headstand yoga posture (Manjunath & Telles, 2003).

Vempati and Telles (2000) examined the effect of yoga on occupational stress through measuring autonomic changes in males after a 2-day yoga workshop. Measures of HRV improved, whereby high frequency power (HF) increased, indicating greater PNS activity, and the low frequency (LF) to HF power ratio decreased, indicating reduced SNS activity. This study was limited by the absence of a control group and was based on a very short exposure to yoga practice, but presents promise for future research.

There are few studies that have examined the effects of various yoga practices on HRV compared to alternative types of intervention. In a randomized controlled trial of yoga including asana compared to standard prenatal exercises in pregnant women, HRV indices significantly increased in the yoga condition incrementally with more continued practice over 36 weeks (Satyapriya, Nagendra, Nagarathna, & Padmalatha, 2009). These measurements, however, were taken directly after yoga practice, and cannot speak to prolonged changes in HRV over time. Similarly, yogis exhibited higher HRV while practicing Iyengar yoga compared to practicing placebo relaxation and compared to control participants, but resting HRV was not compared between yogis and control participants (Khattab, Khattab, Ortak, Richardt, & Bonnemeier, 2007).

Perhaps the highest level of evidence comes from a randomized controlled trial in which elderly participants assigned to a yoga practice including asana showed significantly increased HF power from study baseline, compared to those assigned to aerobic exercise (Bowman et al.,

1997). Though there are clear methodological limitations in this line of research, the available studies do indicate that yoga may increase HRV.

#### **1.3.4 Cardiovascular reactivity and recovery**

Changes in BP and HR in response to a stressor, referred to as cardiovascular reactivity, have been shown to predict resting BP and HR 10 years later (Moseley & Linden, 2006) and to predict the development of hypertension and coronary artery disease (Treiber et al., 2003). A “conceptual sibling” of cardiovascular reactivity that has been too often ignored is cardiovascular recovery, which is the degree to which HR and BP return to baseline levels, either measured by rate to return or by total activation within a recovery period (Linden, Earle, Gerin, & Christenfeld, 1997, p. 117). The inclusion of cardiovascular recovery in study protocols has been fruitful in uncovering positive findings, when results have been null measuring only reactivity (Linden et al., 1997). A meta-analysis of the effect of cardiovascular recovery on longitudinal outcomes concluded that delayed recovery of BP predicts the development of hypertension (Hocking-Schuler & O’Brien, 1997).

In a recent study, Kiecolt-Glaser et al. (2010) found that Hatha yoga experts (defined as individuals who completed one to two yoga sessions per week for at least two years and two yoga sessions per in the last year) displayed significantly lower HR reactivity during a cold pressor task followed by an arithmetic task compared to yoga novices (defined as individuals who completed six to 12 yoga sessions total), though HR recovery, resting HR and BP did not differ between the two groups. In addition to lower HR in response to the stressors, the yoga experts produced less Lipopolysaccharide-stimulated Interleukin-6 in response to the stressors compared

to their novice counterparts, exhibiting less inflammation. BP reactivity and recovery were not reported in Kiecolt-Glaser et al.'s study.

An earlier randomized controlled trial examined the effect of a 6-week yoga intervention on stress reactivity and recovery (Patel, 1975). In this study, hypertensive participants were assigned to yoga with biofeedback or to a passive control condition. Participants in the experimental group showed smaller DBP changes in response to the cold pressor test and quicker return to baseline values, compared to control participants. A nonrandomized controlled trial reported quicker returns to baseline following exercise in participants practicing yoga compared to controls (Muralidhara & Ranganathan, 1982).

Although the effect of yoga, including asana, on stress reactivity and recovery has not been studied extensively, meditation has been subjected to more scientific inquiry. Three randomized controlled trials and one cross-sectional study examined the stress response of meditators and yielded mixed results. In a cross-sectional study of experienced practitioners of Transcendental meditation (TM) compared to individuals with no meditation experience, meditators showed quicker returns to baseline HR and reported less subjective anxiety after being exposed to a stress-inducing film depicting workplace accidents entitled “It didn’t have to happen” (Goleman & Schwartz, 1976). The study found greater HR and skin conductance in the meditators in anticipation of the accidents. The authors posit that, although cardiovascular reactivity is considered maladaptive, considering the greater associated recovery, the observed response may represent an adaptive awareness that enhances coping (Goleman & Schwartz, 1976).

In a randomized controlled trial, volunteers were assigned to clinically standardized meditation, to progressive muscle relaxation, or to wait-list for four weeks (Lehrer, Schoickett,



Carrington, & Woolfolk, 1980). Participants were asked to use their technique, or sit with eyes closed for controls, after the administration of loud tones. Meditators exhibited higher HR in anticipation of the tones, but reduced HR after the tones compared to the other groups.

In a study of similar design by the same authors, anxious participants were assigned to clinically standardized meditation, progressive muscle relaxation or wait-list (Lehrer, Woolfolk, Rooney, McCann, & Carrington, 1983). Participants were asked to use their techniques after being exposed to the loud tones, and to the film “It didn’t have to happen”. HR was again found to decline significantly more in meditators compared to the other groups after the administration of the loud tones. No significant differences were found in the recovery period after the film.

In the most recent randomized controlled trial comparing the cardiovascular reactivity of participants assigned to four months of transcendental meditation (TM) or to cognitive-based stress education, no differences in stress reactivity were observed in response to cognitive stressors (a Serial 13 task and Star tracing task) or to a physical stressor (Handgrip task) (Wenneberg et al., 1997).

### **1.3.5 Respiration rate**

Respiration rate is closely tied to HR and has been examined in at least nine studies (Innes et al., 2005). Seven of these reported significant reductions after yoga intervention, up to 60%. In a cross-sectional study published since Innes et al.’s review paper, regular yogis were compared to regular marathon runners and non-obese sedentary medical students (as controls) on measures of lung function (Prakash, Meshram, & Ramtekkar, 2007). It was concluded that yogis and runners have similar lung function, but that yogis have superior Peak Expiratory Flow Rates (PEFR), an index of respiratory health.

### **1.3.6 Anthropometric measures**

The majority of published studies that have measured changes in body composition including body weight, body fat percentage, body mass index, and waist-hip circumference associated with yoga practice, have reported significant improvement (Innes et al., 2005). Of the randomized controlled trials, five of six reported significant improvement. The only randomized controlled trial that included an active control, found significant improvement with a 14-week yogic lifestyle intervention including asana compared to an exercise and diet education in participants at risk of coronary artery disease and in patients with ischaemic heart disease (Mahajan, Reddy, & Sachdeva, 1999). A pilot study published recently showed that yoga practice, compared to wait-list control, significantly reduced waist circumference by an average of 3 centimetres, though weight was unchanged, in a sample of overweight or obese breast cancer patients (Littman et al., 2011).

## **1.4 Does yoga improve mental health?**

The psychological factors that have accrued the most empirical support in their association with cardiovascular disease are depression, perceived stress, anxiety, hostility, and low social support (Krantz & McCeney, 2002), and these were therefore of interest in this study. Mindfulness, a relatively new construct, is of interest due to its conceptual link with yoga practice and due to its association with positive mental health outcomes, and was therefore examined in this study. A brief review follows of research examining the effect of yoga on these variables.

#### **1.4.1 Perceived stress and anxiety**

Yoga may be presumed by the lay North American public to be a relaxation technique that reduces perceived stress. Yet, it was not until recently that yoga has been employed with the intention of relaxation rather than for deeper spiritual meaning. Moreover, the basic tenet that yoga reduces stress has yet to be scientifically established. There is a paucity of studies that actually measure the effect of yoga on stress as a main hypothesis. When self-reported perceived stress is measured as part of a larger battery of measures, the results have been generally favourable (e.g., Granath, Ingvarsson, von Thiele, & Lundberg, 2006; Smith, Hancock, Blake-Mortimer, & Eckert, 2007). It is assumed that stress reduction is a mediator through which yoga affects cardiovascular health, but this mediation hypothesis has not been tested. In a study with at least some evidence of stress reduction as a mediator, a two-day yoga intervention was shown to reduce cardiovascular risk indices only in individuals with high initial stress levels (measured with the Occupational Stress Index), suggesting that stress reduction is the pathway of change (Vempati & Telles, 2000). Even in this study, however, changes in perceived stress levels were not assessed nor tested as mediators. Findings are not unanimous on this issue, as another intervention study revealed reduced BP in the yoga intervention group, while perceived stress did not change (Latha & Kalliappan, 1991).

Anxiety is more commonly studied in the yoga literature than perceived stress. In the first and only systematic review of the effect of yoga on anxiety (Kirkwood, Rampes, Tuffrey, Richardson, & Pilkington, 2005), a total of eight relevant studies were identified; six were randomized controlled trials and two were non-randomized controlled trials. The authors determined that it was not possible to draw conclusions about the effectiveness of yoga in treating anxiety disorders largely due to the poor quality of studies. Another limitation is that,

even when the research question is narrowed down to the effect of yoga on anxiety, the wide variation in anxious populations studied precludes generalization. Populations include participants with examination anxiety, snake phobia, obsessive-compulsive disorder (OCD), “anxiety neurosis” (Sahasi, Mohan, & Kacker, 1989; Sharma, Azmi, & Settiwar, 1991) and “psychoneurosis” (Vahia et al., 1973).

Kirkwood et al. (2005) searched for studies with anxiety-related primary outcome variables, and did not include studies that measure anxiety as part of a large battery of psychological measures. While the studies must be interpreted with caution, it is of note that they all report significant positive effects of yoga on anxiety. Each study reports significant group differences between the yoga group and the control group. The type of control varied considerably by study, and included other behavioural interventions, placebo tablet, and medication (diazepam or amitriptyline and chlordiazepoxide).

By the reviewer’s account, the most methodologically sound of the included studies was that of Shannahoff-Khalsa et al. (1999). This randomized controlled trial assigned adults diagnosed with obsessive-compulsive disorder (OCD) to a Kundalini yoga group (meditation and breathing exercises) or to a mindfulness meditation group for three months. Mean reduction on the Yale-Brown Obsessive Compulsive Scale (Y-BOCS) was considerable for the yoga group ( $M = 9.43$ ,  $SD = 7.21$ ), and significantly larger than that of the meditation group. The groups then both received the yoga intervention for an additional year, and Y-BOCS scores were reduced by an impressive 71%. It must be noted that, although the study was identified as methodologically sound by comparison, it still has a host of serious interpretive problems: 1) The attrition rate of the study was high at 42% for the yoga group and 30% for the meditation group, 2) the sample size was small, with only 7 remaining participants in each group, and 3) the absence of a passive

control group makes it difficult to interpret the effect of the yoga group. A wait-list control, in addition to meditation, would have been more informative, and a comparison with cognitive-behavioural therapy would be the most informative. Although these caveats cannot be ignored, the study presents exciting findings.

To identify randomized controlled trials published after Kirkwood et al.'s (2005) review, a search performed in PsycInfo using the search terms [yoga] and [anxiety or stress], between the years 2004 and 2011 was performed. One full-scale randomized controlled trial, one small randomized-controlled trial, and one feasibility study were identified that tested the effects of yoga including asana on anxiety or perceived stress. The full-scale randomized controlled trial included a sample of participants with mild to moderate levels of perceived stress who were assigned to 10 weekly sessions of either yoga asana and breath awareness or progressive muscle relaxation (Smith et al., 2007). Both groups significantly and similarly improved on measures of perceived stress and anxiety. No passive control group was included. In a smaller randomized controlled trial, 22 Bihar flood survivors were randomly assigned to a 7-day daily yoga intervention or wait-list intervention (Telles, Singh, Joshi, & Balkrishna, 2010). No differences between groups were found on measures of fear, anxiety, disturbed sleep, or sadness assessed by visual analog scales. An uncontrolled feasibility study examined 12 incarcerated female participants, of whom six completed the study (Harner, Hanlon, & Garfinkel, 2010). The group experienced a marginally significant decrease in anxiety, and no change in perceived stress.

Five other randomized controlled trials were identified that measured the effects of yoga on anxiety, but not as a primary outcome. The studies were conducted with diverse patient populations including migraine sufferers without aura (John, Sharma, Sharma, & Kankan, 2007), irritable bowel syndrome in adolescents (Kuttner et al., 2006) and in adults (Taneja et al., 2004),

women who identify as dissatisfied with their bodies (Mitchell, Mazzeo, Rausch, & Cooke, 2007), and with a healthy sample of employees at a Swedish company (Granath et al., 2006). Anxiety was reduced in all the studies, with the exception of one (Mitchell et al., 2007). Participants' anxiety scores improved in Granath et al.'s (2006) study, but did not exceed the reduction of the comparison group receiving cognitive behavioural therapy.

#### **1.4.2 Depression**

In a review of the effect of yoga on depressive symptoms in participants classified as depressed (Pilkington, Kirkwood, Rampes, & Richardson, 2005), five relevant randomized controlled trials were identified. Promisingly, all five studies show that yoga is effective in reducing depressive symptoms as well or better than standard care. These studies vary in a number of important ways. The studies included different types of yoga including Savasana (Khumar, Kaur, & Kaur, 1993), Iyengar (Woolery, 2004), Sudarshan Kriya yoga (Janakiramaiah et al., 2000; Rohini, Pandey, Janakiramaiah, Gangadhar, & Vedamurthachar, 2000), and Broota relaxation (Broota & Dhir, 1990). The length of the intervention also varied between studies and ranged from three sessions over three days (Broota, Varma, & Singh, 1995) to two sessions over five weeks (Woolery, Myers, Sternlieb, & Zeltzer, 2004). Finally, participants ranged in terms of type and severity of depression including mild depression (Woolery et al., 2004), major depression (Janakiramaiah et al., 2000; Rohini et al., 2005), severe major depression (Khumar et al., 1993), and “neurotic or reactive” depression (Broota et al., 1995). In order to identify relevant studies published since Pilkington et al.'s (2005) review, a search using PsycInfo with the search terms [yoga] and [depression or depressed] between the years 2005-2011 was conducted. Only one additional study examined an intervention primarily comprised of yoga asana in a depressed

population. A pilot study investigated an open trial of Vinyasa yoga over eight weeks, in which 10 persistently depressed individuals could participate in unlimited free yoga classes at a yoga studio (Uebelacker et al., 2010). The study found significantly lower depression and significantly higher mindfulness and behavioural activation at follow-up. Limits of this study are the lack of control group and the payment of participants for each yoga class they attended, which does not generalize to natural yoga uptake.

Other studies have examined the effect of yoga on depressive symptoms in non-depressed populations. To date, there is no review of these studies. Nonetheless, there is promise that, even in samples that are not chosen by depression status, depressive symptoms can be reduced through yoga. For example, depressive symptoms have been shown to decrease after yoga intervention in college students (Berger & Owen, 1992), in healthy participants aged 20-25 (Ray, 2001), in older adults in a residential home (Krishnamurthy, 2007), in alcohol dependent individuals (Janakiramaiah et al., 2006), in individuals with anxious complaints (Kozasa et al., 2008), and in incarcerated females (Horner et al., 2010). No change in depression scores was observed in adolescents with irritable bowel syndrome (Kuttner et al., 2006).

The mechanism by which yoga is generally proposed to alleviate depression, or to improve mood, is through stress reduction, based on the comorbidity of perceived stress and depression (Jorm, Christensen, Griffiths, & Rodgers, 2002). Studies, however, do not specifically test whether yoga reduces depression above and beyond reducing perceived stress. There is recent evidence that a single session of yoga increases positive affect compared to active and passive control conditions (Kiecolt-Glaser et al., 2010). Yoga has also been shown to improve mood, rather than depressive symptoms, in a community sample randomly assigned to Iyengar yoga or walking (Streeter et al., 2010).

### **1.4.3 Hostility**

Hostility has been linked to poor cardiac outcomes (Smith & Pope, 1990) and cardiovascular disease markers (Sloan, 2001). There is a paucity of research assessing the impact of yoga practice on hostility, but at least one study measured the effect of yoga practice on hostility and demonstrated a significant reduction (Bhushan & Sinha, 2001), and another study demonstrated a reduction in hostility immediately following yoga practice (Lavey et al., 2005). Anger has been demonstrated to decrease after just three sessions of yoga, but hostility was not measured (Berger & Owen, 1992). In theory, an adoption of yogic principles for living could reduce hostility, but an empirical association cannot be made at this time.

### **1.4.4 Social support**

Social support is a variable that is linked to cardiovascular risk factors. It is not known whether yoga practice has an effect on social support, but intervention studies are certainly confounded by social support when the comparison condition does not include social contact. In the real world, yoga can be practiced individually or in groups. Social contact is therefore increased in individuals who regularly practice in groups, although interaction may be limited. Yogic philosophy could also influence social functioning by emphasizing prosocial concepts.

### **1.4.5 Mindfulness**

Trait mindfulness is the tendency to attend to the present moment without judgment, and has been shown to predict lower rates of psychopathology (Lau et al., 2006). Yoga differs from typical Western exercise by combining focused attention with breath and movement. At least two studies have reported increased trait mindfulness with yoga training. In a cross-sectional study of individuals who have practiced yoga asana for more than five years and those who have practiced



for less than five years, longer history of practicing yoga was associated with greater mindfulness, measured by the Mindful Attention Awareness Scale (MAAS; Brisbon & Lowery, 2009). In a pilot randomized controlled trial of eight weeks of Hatha yoga or wait-list, mindfulness increased in both conditions, as measured by the Freiberg Mindfulness Inventory, and differences between the groups were unfortunately not reported (Shelov, Suchday, & Friedberg, 2009).

### **1.5 Does yoga exert a generalized or specific stress-reducing effect?**

Since the 1970s, there has been debate about the nature of stress reduction. Benson (1975) proposed that stress management or self-regulation techniques exert their effects by a single generalized relaxation response in multiple physiological systems. An alternative theory, the specificity hypothesis, was proposed by Davidson and Schwartz (1976), whereby specific cognitive effects were hypothesized to result from cognitively focused techniques, and specific somatic effects were hypothesized to result from somatically focused techniques. Shortly after, they revised their hypothesis to instead posit that particular techniques produce specific effects superimposed on a generalized relaxation response (Schwartz, Davidson & Goleman, 1978). Their hypothesis is based on a) the assumption that cognitive anxiety and somatic anxiety are two independent types of anxiety, and b) the multiprocess theory (Davidson & Schwartz, 1976), which posits that the self-generation of cognitive activity reduces cognitive anxiety, whereas the self-generation of somatic activity reduces somatic anxiety, by competing for limited 'channel space'. Support for this theory is limited, as it was derived from the finding that auditory stimuli interfere more with detection of auditory stimuli, while visual stimuli interfere more with the

detection of visual stimuli (Segal & Fusella, 1970). I am not aware of a study from cognitive science that directly tests this effect with cognitive stressors and somatic stressors.

There is support for the claim that cognitive anxiety and somatic anxiety are separate anxiety constructs that do not necessarily hang together theoretically or statistically (Hamilton, 1959; Buss, 1962; Barret, 1972). Cognitive anxiety describes fears, phobias, obsessions, and ruminations, while somatic anxiety describes signs of autonomic-endocrine activity (e.g., sweating, heart palpitations) and skeletal-motor tension (e.g., muscle aches, restlessness). Note that, in this literature, cognitive anxiety includes both affective and cognitive symptoms of anxiety. This is in contrast to the classification of the Personality Assessment Inventory (PAI; Morey, 1991), which includes three distinct subscales (cognitive, affective, and physiological), whereby the cognitive subscale refers specifically to cognitive difficulties associated with anxiety. The majority of evidence suggests that anxiety is better characterized by a two-factor structure. For example, item analysis of frequently used anxiety questionnaires (Barrett, 1972) and factor analysis of self-report questionnaires in psychiatric populations demonstrated that cognitive anxiety and somatic anxiety comprise two factors (Buss, 1962; Hamilton, 1959). The Beck Anxiety Inventory (BAI), a common measure of global anxiety symptoms, was shown to be comprised of two factors by factor analysis as well (Hewitt & Norton, 1993).

Several studies using varying methodologies have been conducted to test the specificity hypothesis, yielding mixed results. The first was a cross-sectional study of regular practitioners of aerobic exercise and regular practitioners of meditation (primarily Transcendental Meditation). The exercisers reported less somatic anxiety than the meditators, and the meditators reported less cognitive anxiety than the exercisers, validating the Davidson and Schwartz's (1976) specificity

hypothesis (Schwartz, Davidson, & Goleman, 1978). This study also introduced the Cognitive and Somatic Anxiety Questionnaire (CSAQ).

In another cross-sectional study, regular players of recreational sport, regular recreational exercisers, regular meditators, and sedentary controls were administered the CSAQ (Steptoe & Kearsley, 1990). No group differences were found on any of the anxiety measures. Therefore, the results did not confirm that meditation is associated with particularly reduced cognitive anxiety, and that exercise is associated with reduced somatic anxiety, but the hypothesis of specificity was not disproved by these overall null findings.

Limited support for the specificity hypothesis was found in the previously described randomized controlled study by Lehrer et al. (1980), in which volunteers were assigned to clinically standardized meditation, progressive muscle relaxation or wait-list for four weeks and examined on physiological and psychological signs of anxiety in response to loud tones. Participants were asked to use their respective techniques after the administration of the tones. Meditators reported less symptoms of cognitive anxiety than the other two groups. Unfortunately, the cognitive and somatic anxiety symptoms were measured by a non-validated questionnaire constructed for the study.

In another previously described study of similar design by the same authors, anxious participants were assigned to clinically standardized meditation, progressive muscle relaxation or wait-list (Lehrer et al., 1983). Loud tones were administered, as well as the addition of the stress-inducing film entitled “It didn’t have to happen” depicting workplace accidents. Participants were asked to use their techniques. In this study, the Lehrer Woolfolk Trimodal Anxiety Symptom Questionnaire (Lehrer & Woolfolk, 1982) showed that the meditation group significantly decreased in trait somatic, cognitive, and behavioural subscales, and that the progressive muscle

relaxation group decreased only in the cognitive subscale. This is inconsistent with predictions of the specificity hypothesis. The authors posit that this was due to random fluctuations rather than a true effect, as it was not replicated in another study, which found no changes on the Woolfolk Trimodal Anxiety Symptom Questionnaire, whether in a meditation, progressive muscle relaxation, or self-monitoring control group (Woolfolk, Lehrer, McCann, & Rooney, 1982).

Despite the unconvincing findings, Lehrer, Carr, Sargunraj, and Woolfolk (1994) concluded in a review paper that stress management techniques do exert specific effects; however, the authors abandon the cognitive/somatic anxiety distinction. Lehrer and colleagues argued that cognitively oriented methods have cognitive effects, autonomically oriented methods have autonomic effects, and muscularly oriented methods have muscular effects. The authors also argued that disorders that are predominantly muscular are best treated by muscularly oriented techniques, that disorders that are predominantly autonomic are best treated by autonomically focused techniques, and that stress-related mental disorders that have cognitive and behavioural components are best treated by cognitive and behavioural methods. Their conclusions do not rule out a generalized relaxation response upon which specific effects may be superimposed.

Several measures have been developed to measure cognitive anxiety and somatic anxiety separately. The first of these measures was the Cognitive and Somatic Anxiety Questionnaire (CSAQ; Schwartz, Davidson, & Goleman, 1978), which is a 14-item self-report questionnaire comprised of two seven-item subscales. It was constructed by selecting face-valid items from commonly used questionnaires. The CSAQ has some psychometric weaknesses that have been pointed out over two decades ago, but have never been addressed (DeGood & Tait, 1987). Investigators failed to find a correlation between full scores and the Spielberger Trait Anxiety Inventory (STAI) in females, posing a serious problem for concurrent validity (DeGood & Tait,

1987). The CSAQ asks respondents to indicate the symptoms they typically experience when anxious. It is, therefore, neither a trait nor a state scale, which could explain the lack of correlation with the STAI. DeGood and Tait (1987) recommended adding questions about frequency of experiencing stated symptoms.

The State-Trait Inventory for Cognitive and Somatic Anxiety (STICSA; Ree, MacLeod, French, & Locke, 2000) is a recently developed questionnaire that assesses cognitive anxiety and somatic anxiety symptoms using separate state and trait scales. Each scale is comprised of the same 21 items (10 assessing cognitive anxiety, 11 assessing somatic anxiety). The trait version (STICSA-T) asks respondents: “how often, in general, the statement is true”. The state version asks respondents: “how you feel right now, at this very moment, even if this is not how you usually feel”. The cognitive and somatic components of the STICSA-S have been shown to respond differentially to stressors. Specifically, it has been demonstrated that cognitive anxiety increases significantly more than somatic anxiety in response to examination stress, while somatic anxiety increases significantly more than cognitive anxiety in response to inhalation of carbon dioxide-enriched air (Ree, French, MacLeod, & Locke, 2008).

The relationship between the STICSA-T and the STICSA-S is worthy of attention. Trait cognitive anxiety and trait somatic anxiety did not predict the type of state anxiety an individual experienced under stress, but rather the type of stressor to which an individual was likely to more strongly react (Ree et al., 2008). Baseline trait cognitive anxiety, but not baseline trait somatic anxiety, predicted both somatic and cognitive state anxiety in response to a cognitive stressor, while baseline trait somatic anxiety, but not baseline trait cognitive anxiety, predicted both somatic and cognitive state anxiety in response to a somatic stressor (Ree et al., 2008).

Given the findings on the relationship between the STICSA-T and the STICSA-S, the results of studies using the CSAQ may be misinterpreted. The CSAQ has never been studied in relation to stress induction. Because no study has looked at the specificity question by inducing specific types of laboratory stress and comparing anxiety reactions with validated measures, the specificity question has not yet been sufficiently addressed. Making this distinction is vital to extending clinical applications from this line of research. If it is true that specific activities differentially reduce cognitive anxiety and somatic anxiety symptoms, then it follows that clinicians could assign these activities based on the relative cognitive to somatic anxiety levels of the patient or client. However, if it is instead the case that specific activities differentially reduce the total stress response to cognitive or somatic stressors, the clinician would assign these activities based on the type of stressor to which the patient or client is likely to more strongly react.

Theoretically, the prediction that stress-reducing techniques differentially affect the stress response to cognitive versus somatic stressors may be based on the assumption that different techniques expose individuals to different types of stressors. Therefore, because runners frequently experience the physical ‘stress’ of running, they may have an attenuated stress response to other physical stressors. Essentially, they may habituate to physical sensations associated with cardiovascular activity. Meditators, on the other hand, may have had to confront a good deal of cognitive stress while meditating, at least in the early stages of their practices. By continuing to meditate through this potential discomfort, they may habituate to cognitive anxiety, which may apply to cognitive stressors more broadly. In practitioners of yoga who practice Hatha yoga with asana and meditative components, habituation may occur in both somatic and cognitive domains, based on exposure.

In summary, the research literature on the potential physiological and psychological benefits of yoga has been fairly superficial, especially in that specificity has been lacking. In order to test for specificity of effects in yoga, a group of regular runners will be examined in addition to a sedentary group that does not regularly participate in any activity aimed at reducing perceived stress or improving aerobic fitness. Running has been shown to improve many of the previously discussed physiological and psychological variables involved in cardiovascular health. By comparing yoga practitioners (yogis) with runners and with sedentary individuals, we could identify group differences that are specific to yoga, and suggest potential mechanisms (e.g., psychological variables, lifestyle variables, anthropometric variables, respiration, aerobic fitness) of yoga's potential benefits to cardiovascular health.

## **1.6 The physiological effects of running**

### **1.6.1 BP**

In the most recent meta-analysis of the effect of aerobic exercise on BP, the results of 54 randomized controlled trials were synthesized to reveal a 3.84 mmHG reduction in SBP and a 2.58 mmHG reduction in DBP by aerobic exercise participation (Whelton, Chin, Xin, & He, 2002). Reductions were significant for hypertensives and normotensives, as well as overweight and non-overweight participants. All frequency schedules, intensities, and types of aerobic exercise were found to lower BP.

In a meta-analysis of the effect of endurance training on resting BP, a 3.0 mmHG ( $p < .001$ ) reduction in SBP was found and a 3.3 mmHG ( $p < .01$ ) reduction in DBP was found (Cornelissan & Fagard, 2005). Changes were more pronounced in hypertensive samples, but were also significant in normotensive samples. Most of this literature is based on randomized

controlled trials in which participants are assigned to exercise groups. These studies likely underestimate the true potential of exercise to influence BP, because of the difficulty in assigning exercise of high intensity or increasing fitness levels over an extended length of time. In a cross-sectional study of a large sample of individuals who run regularly, individuals who run faster had lower BP, indicating increased returns on increasing the intensity of physical activity (Williams, 1998). Causality could not be determined due to a lack of controlled trials.

### **1.6.2 HR**

Data by meta-analysis reveal consistent reductions in resting HR by exercise intervention. In a meta-analysis of the effects of aerobic exercise as assigned in randomized controlled trials on various physiological measures, exercise groups showed a significantly reduced overall HR of five beats per minute compared to control groups (Kelley, Kelley, & Tran, 2001). Similarly, in a more specific meta-analysis that only included studies that examined the effects of endurance training assigned in randomized controlled trials, the exercise groups showed an overall reduction of 4.8 beats per minute compared to controls groups (Cornelissen & Fagard, 2005).

### **1.6.3 HRV**

It is accepted that HRV is positively related to aerobic capacity (Hedelin, Wiklund, Bjerle, & Henriksson-Larsen, 2000; Pardo et al., 2000), but the majority of research on aerobic activity and HRV do not focus specifically on running. The results of the few existing studies are inconsistent.

In a cross-sectional study which examined HRV in a group of 72 male runners compared to age and weight matched sedentary controls, HRV will be measured at rest and demonstrated significantly higher levels of HRV in the running group than in the controls (De Meersman,



1993). Significant increases in HRV were also found following a 12-week running training program, as compared with pre-training values (Carter, Banister, & Blaber, 2003).

However, other studies have found no association between running and enhanced HRV. No change was found in HRV between a group of middle-aged men who completed eight weeks of running training compared to an age-matched control group (Boutcher & Stein, 1995). No changes in HRV were found in a group of middle-aged men following a five-month exercise training program with no control group (Loimaala, Huikuri, Oja, Pasanen, & Vuori, 2000).

#### **1.6.4 Stress reactivity and recovery**

The cross-stressor adaptation hypothesis (Sothmann et al., 1996) posits that adaptation to exercise, a physical stressor, generalizes to adaptation to other stressors, whether they are physical or psychological. In the first meta-analysis on the effects of aerobic fitness on cardiovascular reactivity to laboratory stressors, aerobic fitness was shown to predict attenuated stress reactivity when measured by SBP, but not by DBP or by HR (Crews & Landers, 1987). In the most recent meta-analysis to date, methodological weaknesses of Crews & Landers' (1987) seminal meta-analysis were addressed and recovery was added (Forcier et al., 2006). Results revealed that fitness was associated with attenuated stress reactivity as measured by HR and SBP, but was unrelated when measured by DBP. Aerobic fitness was associated with an attenuated response in the recovery period only when measured by HR. It should be noted that a meta-regression analysis published in the same year presented different conclusions, based on more liberal inclusion criteria (Jackson & Dishman, 2006). Overall, the data did not support the hypothesis that fitness level predicts attenuated stress reactivity.

Specifically, in cross-sectional studies, the effect of membership in exercise groups on various physiological measures of reactivity was non-significant, based on 208 effects. Overall, fitness level was associated with a small but significantly greater *increase* in HR reactivity to stressor. In cross-sectional studies, the effect of membership in exercise group on various physiological measures of recovery was non-significant, based on 51 effects. Even with these meta-analyses in mind, the relationship between aerobic fitness and cardiovascular measures of stress reactivity and recovery remains unclear.

## **1.7 The psychological effects of running**

### **1.7.1 Anxiety**

There have been at least six meta-analyses of the effect of exercise participation on anxiety (Kugler, Seelback, & Kruskemper, 1994; Landers & Petruzzello, 1994; Long & van Stavel, 1995; McDonald & Hodgdon, 1991; Petruzzello, Landers, Hatfield, Kubitz, & Salazar, 1991; Schlicht, 1994). With the exception of one (Schlicht, 1994), each meta-analysis revealed significant reductions compared to control groups, ranging from small to moderate overall effect sizes. Effects are significant whether exercise participation is acute or chronic, but effect sizes are larger when the length of aerobic training is greater than 10 weeks. Effects remain whether exercise is aerobic or anaerobic, but larger effects are shown when exercise is aerobic (Landers & Petruzzello, 1994; Petruzzello et al., 1991). Exercise-induced stress reduction was especially pronounced in samples with high levels of work-related stress (Long & van Stavel, 1995). It is noteworthy that although the meta-analyses reveal that exercise has anxiolytic effects, these effects are estimated to last less than six hours (Landers & Petruzzello, 1994), and have not been

clearly demonstrated to be superior to anxiety-reducing treatments such as cognitive behavioural therapy or relaxation training.

### **1.7.2 Depression**

At least six meta-analyses have been published on the effect of exercise on depression, each concluding that exercise, whether acute or chronic, is effective in reducing self-reported depressive symptoms (Calfas & Taylor, 1994; Craft & Landers, 1998; Kugler, Seelback, & Kruskemper, 1994; Lawlor & Hopker, 2001; McDonald & Hodgdon, 1991; North, McCullagh, & Tran, 1990). The effects were generally of moderate magnitude, and were sometimes greater than the effects of traditional treatments such as psychotherapy (Craft & Landers, 1998). Depressive symptoms were reduced in clinically depressed and non-depressed samples, and this reduction was consistent across various exercise modalities, whether aerobic or anaerobic (North et al., 1990). Although the results of the most recent meta-analysis indicated that exercise reduced depressive symptoms comparably to cognitive therapy, the authors concluded that methodological weaknesses in included studies limit conclusions and they suggested longer follow-ups and the use of clinical populations (Lawlor & Hopker, 2001).

### **1.7.3 Hostility**

While the effect of exercise on hostility has not been a major research topic, hostility has been examined secondarily in studies that use the Profile of Mood States (POMS), which includes an anger-hostility subscale. In a review of studies that examine the effects of exercise using the POMS (Berger & Motl, 2000), results are mixed. It appears that acute effects are found more often than long-term effects when using the POMS with non-clinical samples, though chronic effects have been found as well.

#### **1.7.4 Social support**

The present study is the first to assess whether regular runners have particularly high social support. Social support has been suggested as a possible partial mediator for the beneficial effects of exercise on mental health in the context of intervention studies, although this model has not been explicitly tested (Lawlor & Hopker, 2001; North et al., 1990). A cross-sectional study of adolescents demonstrated a correlation between physical activity level and social functioning, which remained significant after controlling for age, gender, and socioeconomic status, while the relationship between activity and depression/anxiety was not significant after controlling for these factors (Allison, 1990). It is not understood how physical activity could improve social functioning. Running is an activity that could be completed individually or socially, as part of a running group or in marathons. Running could have direct benefits on social functioning or could increase social support through increased social contact.

#### **1.7.5 Mindfulness**

I am not aware of any study that specifically measures trait mindfulness in runners, either cross-sectionally or in an intervention. There are aspects of running, however, that could promote mindfulness including synchronization of breath and movement, and minimal distraction.

### **1.8 The present study**

Yoga is a complex system of Indian thought that dates back as far as 7000 years. The practice of yoga in North America today is largely focused on asana (physical postures). The majority of Canadians who have tried yoga have done so to prevent future illness or to maintain health (Esmail, 2007). Yoga has been implicated in the treatment of an overwhelming number of health conditions (Shannahoff-Khalsa, 2004; Singh, 2005), the most promising of which is

cardiovascular disease (Innes et al., 2005). Reviews on the effect of yoga on cardiovascular health reveal pervasive methodological weaknesses that make it difficult to reach conclusions. Moreover, there is a paucity of research that compares yoga with other practices, thereby preventing specific claims to be made about the benefits of yoga. Additionally, there is an absence of research testing the mechanisms underlying the cardiovascular health effects of yoga.

The present study assessed psychological and physiological markers of cardiovascular health in a group of regular practitioners of yoga, including physical postures and meditation, compared to a group of regular runners and a group of participants who do not regularly engage in any relaxation or exercise practices. Conclusions can therefore be made about yogis specifically, and not about the act of regular exercise or regular practice of any kind. The inclusion of the running group also facilitated testing Davidson and Schwartz's (1976) specificity hypothesis, which predicted that the yoga group would report less cognitive and somatic anxiety and display less cardiovascular activation in response to cognitive and somatic stress, while the purely physical running group would only report less somatic anxiety and display less cardiovascular activation in response to somatic stress compared to controls.

The physiological markers of cardiovascular health that were measured include HR and BP at rest, during and in recovery from laboratory stress induction, as well respiration and HRV at rest. By including a running group, greater specificity could be gained about the differences found between the yoga group and the control group. The study also examined group differences in psychological variables, including depression, hostility, perceived stress, anxiety, and social support, that are important in their own right and also as contributors to cardiovascular health. Finally, the study examined group differences in aerobic fitness, waist circumference and lifestyle factors associated with cardiovascular health, including sleep quality, vegetarianism, and

substance use. By examining these group differences, the study explored mechanisms to explain potentially superior physiological markers of cardiovascular health in yoga practitioners compared to sedentary individuals.

### **1.8.1 The hypothesized model**

A theoretical model of the potential effects of yoga has not been previously tested. The present study's research questions are based on a model with five hypothesized pathways predicting physiological markers of cardiovascular health, displayed in Figure 1. The hypothesized model teases apart the contributions of psychological factors (depression, anxiety, perceived stress, hostility, social support), lifestyle factors (sleep, substance use, vegetarianism), aerobic fitness, waist circumference, and respiration rate to physiological markers of cardiovascular health. While the cross-sectional design of the present study prohibits exploration of causal relationships and the comprehensive testing of this model, the present study lays the groundwork for such exploration.

### **1.8.2 Specific hypotheses**

#### **1.8.2.1 Resting physiological measures**

Based on previous research described by Innes et al. (2005), I predicted that the yoga group would have lower resting HR, SBP and DBP compared to the sedentary group. I predicted that the yoga group would not differ from the running group on these measures. As has been previously demonstrated by randomized controlled trial of yoga compared to exercise (Bowman et al., 1997), I predicted that the yoga group would have higher HRV (measured by HF) compared to the sedentary group and also compared to the runners, though I also predicted that the runners would have higher HF power compared to the sedentary group.

### **1.8.2.2 Cardiovascular reactivity and recovery**

Based on the limited research on stress reactivity in individuals assigned to yoga intervention (Patel, 1975; Muralidhara & Ranganathan, 1982), I hypothesized that the yoga group would show decreased cardiovascular reactivity, as measured by HR, SBP and DBP, compared to the running group and sedentary group, under both stress conditions. However, the previously described research on stress reactivity in meditators contrasts with this hypothesis, because the meditation group showed increased activation during stress exposure, but decreased activation in the recovery period (Goleman & Schwartz, 1976; Lehrer et al., 1980). Based on these studies, I hypothesized that the yoga group would show superior recovery compared to the sedentary group. I predicted that the running group would also show less sympathetic activation (i.e., less reactivity and superior recovery) compared to the sedentary group, (based on meta-analytic findings by Forcier et al., 2006), although past findings have been mixed (Jackson & Dishman, 2006).

Extending Schwartz et al.'s (1978) hypothesis that cognitive and somatic relaxation techniques specifically reduce cognitive and somatic anxiety superimposed on a generalized relaxation response, I predicted that sympathetic activation of the yoga group would be equal to that of the running group under the somatic stress condition, but less than that of the running group under the cognitive stress condition.

### **1.8.2.3 Trait somatic and cognitive anxiety**

Consistent with Schwartz et al.'s (1978) hypothesis, I predicted that the yoga group and the running group would report lower trait and state somatic anxiety compared to the sedentary

group, and that only the yoga group would report lower trait and state cognitive anxiety compared to the sedentary group.

I expected to replicate the finding that trait cognitive anxiety and trait somatic anxiety, measured by the STICSA-T, differentially predict the magnitude of total state anxiety change in response to cognitive and somatic stressors, respectively (Ree et al., 2008).

#### **1.8.2.4 Psychological factors**

Based on previously described studies, I predicted that the yoga group would report less depression, perceived stress, anxiety, and hostility compared to the sedentary group. I predicted greater social support in the yoga group based on yogic philosophy, in the absence of previous research. There is evidence from previously described past research that running is associated with reductions in anxiety and depressive symptoms, though the research on running and hostility and social support is sparse. I predicted that the yoga and running groups would score similarly on the psychological variables. I predicted the yoga group would display greater mindfulness compared to the sedentary group and the running group, given the previous findings that mindfulness increases with yoga practice (Shelov et al., 2009) and with longer history of yoga practice (Brishon & Lowery, 2009).

#### **1.8.2.5 Lifestyle factors**

Though there is a paucity of previous research on yoga and lifestyle factors, I predicted that the yoga group would report better sleep quality, higher rates of vegetarianism, and less use of all substances compared to the running group and sedentary group, based on yogic philosophy.



#### **1.8.2.6 Aerobic fitness**

Given the estimated energy expenditure of yoga practice (Ainsworth et al., 2000), I predicted that the aerobic fitness of the yoga group would be superior to the sedentary group, but less than that of the running group.

#### **1.8.2.7 Waist circumference**

Based on past research exploring the effect of yoga practice on anthropometric measures such as Mahajan et al. (1999), I predicted that the yoga group would have smaller waist circumferences compared to the sedentary group. I predicted that the yoga group would not significantly differ from the running group on waist circumference.

#### **1.8.2.8 Respiration rate**

I predicted that the yoga group would display lower respiration rate compared to the sedentary group, but similar respiration rate to the running group, based on previous cross-sectional findings of similar lung function in yogis and running (Prakash, Meshram, & Ramtekkar, 2007).

#### **1.8.2.9 Cardiovascular health indicators**

I predicted that the potential group differences on physiological indicators of cardiovascular health (HR, SBP and DBP at rest and in response to stress, and HRV at rest) would, together, be fully mediated by relevant psychological factors (depression, hostility, perceived stress, anxiety, social support), aerobic fitness, respiration rate, waist circumference, and lifestyle factors (sleep, substance use, vegetarianism).

### **1.8.3 Novel contributions**

The proposed study offers a unique glance at the physiological and psychological functioning of Canadian yoga practitioners. It adds to the previous literature on yoga's potential role in improving performance on measures of physiological and psychological variables linked to cardiovascular health. This was the first study to investigate stress reactivity and recovery in response to cognitive and somatic laboratory stressors in practitioners of yoga compared to an exercise group. Finally, it was the first study to comprehensively measure aerobic fitness, lifestyle factors, waist circumference, respiration rate, and psychological variables in order to better understand how different types of physical activities could impact cardiovascular health.

## **2 Methods**

### **2.1 Participants**

#### **2.1.1 Inclusion criteria**

Individuals from the following three groups were included. First, the yoga group was comprised of individuals who have regularly practiced yoga that includes asana (physical postures) and a meditative component (whether on or off the yoga mat) for at least the past two years. Regular practice was defined as a minimum of three 30-minute sessions of practice including asana per week. Practice could be in a group or individual setting. Second, the running group was comprised of individuals who have regularly run for at least the past two years. Regular practice was defined as a minimum of three 30-minute sessions per week. Running could take place in any setting. Third, the sedentary control group was comprised of individuals who did not regularly participate in any activity intended to reduce perceived stress or improve aerobic fitness. Regular practice was defined as practice lasting at least 30 minutes, one time per week, for any six-month period within the last two years.

#### **2.1.2 Exclusion criteria**

Individuals were excluded if they were not proficient in the English language, or if they were under the age of 20 or over the age of 59. Individuals with a history of any heart disease or known hypertension, including those managing their BP with antihypertensive medication, were excluded from participating. Individuals who identified as yogis or runners were excluded if they regularly participated in any other activity intended for stress reduction or aerobic fitness. Regular practice was defined as practice lasting at least 30 minutes, one time per week, for any

six month period within the last two years. Individuals who use anxiolytic medication or who have a history of panic attacks were excluded.

### **2.1.3 Recruitment strategies**

Participants were offered an honorarium of \$50.00 and recruited by several strategies. We posted advertisements in a local newspaper (The Georgia Straight), on public posting boards, in fitness clothing stores and yoga studios, on the Craigslist Vancouver website, and handed out advertisements in person at a yoga event. We approached the managers of running group organizations who emailed our advertisement to their mailing lists. Some participants offered to recruit their peers.

## **2.2 Measures**

### **2.2.1 Psychological measures**

The psychological factors that have the most support demonstrating their association with cardiovascular disease are depression, hostility, perceived stress, anxiety, and social support (Krantz & McCeny, 2002). Each of these variables have been demonstrated to decrease with yoga practice by at least one randomized controlled trial (Bhushan & Sinha, 2001; Kirkwood et al., 2005; Pilkington et al., 2005; Sahajpal, 2005).

#### **2.2.1.1 Depressive symptoms**

Depressive symptoms were assessed continuously by the second edition of the Beck Depression Inventory (BDI-II; Beck, Steer & Brown, 1996). The BDI-II is a 21-item multiple-choice questionnaire that is a reliable, valid, and widely used instrument in the measurement of depressive symptoms in patient and non-patients populations (Dozois, Dobson, & Ahnberg,

1998). The BDI-II has high internal consistency (Cronbach's  $\alpha = .93$ ) for non-psychiatric participants, as well as adequate validity and diagnostic discrimination ability (Beck et al., 1996). The questionnaire is composed of 21 items, each relating to symptoms or attitudes commonly found among depressed psychiatric patients. Each item is composed of descriptions of increasing severity of the relevant symptoms. Participants choose the appropriate description of their experience of each depressive symptom in the last two-week period. Nineteen of the items provide four choices, ranging from 0 to 3 points. On two items, there are seven choices reflecting an increase or a decrease in appetite or sleep. A sample item is "Sadness. 0) I do not feel sad, 1) I feel sad much of the time, 2) I feel sad all of the time, 3) I am so sad or unhappy that I can't stand it". Summary scores range from 0-63. Cut-offs have been established to describe the degree of depressive symptomatology present, however, due to inconsistent findings regarding the usefulness of these cut-offs, the overall continuous scores were used (Dozois et al., 1998).

Participants were all given a telephone number to a crisis line on the debriefing form. Because the Beck Depression Inventory- II (BDI-II) was the only diagnostic tool used in the study, the research assistant conducting the session reviewed the BDI-II before the participant left the laboratory. When participants obtained a score of 19 or higher, indicating moderate-severe depressive symptoms, they were told that although the test was not designed to diagnose depression, the results indicate the possibility of considerable depressive symptoms, and a resource sheet was given. Eight participants obtained a BDI score of 19 or higher in the study. The research assistant involved in the testing session also checked Question 9 of the BDI-II pertaining to suicidality before the participant left the laboratory. Although research assistants were trained to clarify responses of 2 ("I would like to kill myself") or 3 ("I would kill myself if I

had the chance”) and to seek medical intervention when necessary, no participant in the study indicated these responses.

#### **2.2.1.2 Hostility**

Trait hostility was assessed by the Buss-Perry Aggression Questionnaire (AQ; Buss & Perry, 1992). The AQ is a 29 item scale with four subscales (physical aggression, verbal aggression, anger and hostility). Participants were asked to rate themselves on a one to five scale from “extremely uncharacteristic of me” to “extremely characteristic of me”. A sample item on the Hostility subscale is “When people are especially nice to me, I wonder what they want”. The total score provides a global score of aggression. I was primarily interested in the hostility score. The AQ has shown good internal consistency, both for the global aggression score ( $\alpha = .89$ ) and for each of the subscales ( $\alpha = .72$  to  $.89$ ). Test-retest reliability over seven months is moderately high, ranging from  $r = .67$  to  $r = .82$  (Harris, 1997). Confirmatory factor analysis supported the factor structure of the scale (Buss & Perry, 1992), which was confirmed in a Canadian sample (Harris, 1995).

#### **2.2.1.3 Perceived stress**

Perceived stress was measured by the Perceived Stress Scale-10 (PSS-10; Cohen & Williamson 1988), which is a measure of perceived non-specific stress that has good psychometric properties. Although it is a briefer version than the original 14-item scale, the PSS-10 is improved in terms of factor structure and internal consistency and its use is recommended by the developers of the scale (Cohen & Williamson, 1988). Participants were asked to circle how often they have experienced a given item in the past month out of five possible choices ranging from zero (never) to four (very often). An example item is “In the last month, how often

have you been upset because of something that happened unexpectedly?”. Total scores were used as a continuous measure of perceived stress.

#### **2.2.1.4 Trait cognitive and somatic anxiety**

The State-Trait Inventory for Cognitive and Somatic Anxiety- Trait (STICSA-T) was used, because it is explicitly designed to assess cognitive and somatic anxiety separately, and can also be used to measure general anxiety (Ree, French, MacLeod, & Locke, 2008). The scale is a 21-item self-report inventory that assesses “how often, in general, the statement is true” for participants. Items are rated on a 4-point Likert scale, ranging from one (“not at all”) to four (“very much so”). The scale is comprised of 10 items assessing cognitive anxiety and 11 items assessing somatic anxiety. Sample items include: “I feel agonized over my problems” (cognitive) and “My heart beats fast” (somatic). The STICSA-T was designed explicitly to fit a two-factor model. A split-half reliability coefficient of .87 was found for the cognitive factor and .84 was found for the somatic factor. The STICSA-T has been shown to correlate more with other measures of anxiety than with measures of depression, both in the general population (Ree et al., 2008) and in individuals who are clinically anxious (Gros, Antony, Simms, & McCabe, 2007).

#### **2.2.1.5 State cognitive and somatic anxiety**

The State-Trait Inventory for Cognitive and Somatic Anxiety- State (STICSA-S) is comprised of the same 21 items as the STICSA-T, but respondents are asked to indicate “how you feel right now, at this very moment, even if this is not how you usually feel”. As is the case with its trait counterpart, the structure of the STICSA-S fits a two-factor model. The split half reliability coefficient for the cognitive scale was .9 and .88 for the somatic scale. The STICSA-S has been shown to correlate more with other measures of anxiety than with measures of

depression (Ree et al., 2008). Furthermore, the cognitive and somatic components of the STICSA-S have been shown to increase differentially to stress induction (Ree et al., 2008). The STICSA-S was used as a manipulation check to verify that the handgrip task would induce more somatic anxiety than the arithmetic task, and that the arithmetic task would induce more cognitive anxiety than the handgrip task, and was also used to test hypotheses about differential anxiety change by stressor and by group.

#### **2.2.1.6 Social Support**

The Interpersonal Support Evaluation List (ISEL), which is 40-item questionnaire, was used to assess the perceived availability of social resources. The questionnaire captures four subscales of social support: tangible, appraisal, self-esteem, and belonging. The instrument shows excellent reliability and validity in the general population (Brookings & Bolton, 1988).

#### **2.2.1.7 Mindfulness**

To measure trait mindfulness, we administered the Mindful Attention Awareness Scale (MAAS; Brown & Ryan, 2003). The MAAS is comprised of 15 items. A sample item is “I rush through activities without being really attentive to them”. Participants rate on a scale from one (“almost always”) to six (“almost never”). Total scores are based on a mean of all items, with higher scores representing greater mindfulness. The MAAS has previously shown very good internal reliability, Cronbach’s  $\alpha = .89$  (MacKillop & Anderson, 2007), and this was consistent in our study sample, Cronbach’s  $\alpha = .9$ . No significant test-retest differences in scores were found over a four-week period (Brown & Ryan, 2003). Factor analysis revealed a single factor (Brown & Ryan, 2003). The scale has demonstrated convergent validity by correlating with a variety of predicted well-being constructs and with self-awareness (Brown & Ryan, 2003). Incremental



validity data support the uniqueness of the role of mindfulness in well-being. The MAAS distinguished between individuals who regularly practice Zen meditation and those who do not (Brown & Ryan, 2003), but it was not sensitive in identifying novice-level practitioners (MacKillop & Anderson, 2007). Higher scores correlated with the degree to which individuals perceive that their meditative practice carries over into daily life, and with number of years of practice (Brown & Ryan, 2003). The MAAS distinguished between beginning and advanced yogis, defined as less than or greater than five years of practice (Brisbon & Lowery, 2009).

## **2.2.2 Lifestyle measures**

### **2.2.2.1 Vegetarianism**

To assess vegetarianism, I administered the face-valid question: “A person who eats three meals a day will eat 21 meals in a week. On average, of 21 meals, how many of your meals include meat (including chicken)?”. This provided a continuous measure of meat consumption. Additionally, a categorical measure of diet preference was used, which asked participants if they identify as vegans (individuals who do not eat meat, fish, dairy products, or eggs), lacto-ovo vegetarians (individuals who eat dairy products and/or eggs, but no meat or fish), semi-vegetarians (individuals who eat fish, dairy products and/or eggs, but no meat), or non-vegetarians (individuals who eat meat).

### **2.2.2.2 Substance use**

Alcohol and illicit drug use, was assessed by the Drug Use Frequency (DUF) measure (O’Farrell, Fals-Stewart, & Murphy, 2003). Substances assessed included sedatives, hypnotics, tranquilizers, cannabis, stimulants, heroin, cocaine, phencyclidine (PCP) and hallucinogens. The instrument has shown good concurrent validity, with high correlations between the DUF and the

well-validated Timeline Followback (TLFB) as well as high correlations between the DUF and collateral reports of drug users and partners of users (O'Farrell et al., 2003). The DUF has shown high internal consistency ( $\alpha = .82-.93$ ) and one-week test-retest reliability (.86-.91). An overall agreement rate of 96% was obtained between urinalysis and the DUF (Winters, Stinchfield, Opland, Weller, & Latimer, 2002). The DUF asks about frequency of substance use within the last six months. Example street names are provided. Participants rate each drug on the same zero to seven frequency scale for the past six months (0 = never, 1 = several times, 2 = about once a month, 3 = several times a month, 4 = one to two days a week, 5 = three to four days a week, 6 = five to six days a week, 7 = everyday). Cigarette smoking was assessed using the same frequency scale. Caffeine consumption was assessed by asking for a daily estimate of caffeinated beverages (including coffee, tea, energy drinks, and soda).

### **2.2.2.3 Sleep**

Sleep was assessed by the Pittsburgh Sleep Quality Index (PSQI; Buysse, Reynolds, Monk, Berman, & Kupfer, 1989). The PSQI is a 19-item self-report measure that assesses overall sleep quality and dysfunction over a one-month period. Items range in terms of answer format, with some questions requiring specific answers (e.g., "During the past month, how long (in minutes) has it usually taken you to fall asleep each night?") and some requiring multiple-choice rating (e.g., During the past month, how often have you had trouble sleeping because you cannot get to sleep within 30 minutes? A. Not during the past month, B. Less than once a week, C. Once or twice a week, D. Three times a week or more). The items yield seven scores assessing sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of medication aids for sleep, and daytime dysfunction. Each score ranges from zero to three. The

sum of all scores yields a global score which ranges from zero to 21, with higher scores indicating poorer overall sleep. The global score of the PSQI was used in our study. The global score has demonstrated good internal consistency ( $\alpha=.8$ ) and good test-retest reliability of  $r = .85$  (Buysse et al., 1989).

### **2.2.3 Personality**

Differences between groups on personality were assessed. Because personality is assumed to be stable and to likely precede the uptake of yoga or running, measuring personality provides some insight into whether the study is confounded by characteristics of the participants that are unrelated to their practices. The Ten-Item Personality Inventory (TIPI) was used to measure the Big Five personality domains: extroversion, conscientiousness, openness to experience, agreeableness, and emotional stability. The TIPI has adequate levels of external validity and test-retest reliability (Gosling, Rentfrow, & Swann, 2003), and is suitable for use in our study given that personality is not part of the primary research question and that we have a lengthy questionnaire battery.

### **2.2.4 Physiological measures**

The selected physiological variables were included, because they are markers of cardiovascular disease, and because they have been shown in at least one randomized controlled trial to be positively impacted by yoga practice (Innes et al., 2005).

#### **2.2.4.1 BP and HR**

To measure systolic BP (SBP), diastolic BP (DBP) and HR for resting measures and for response to laboratory stressors, I used the VSM-100 BpTRU automatic BP device, a reliable and

non-invasive tool (Mattu, Heran, & Wright, 2004). The instrument has demonstrated 89% agreement with standard auscultatory mercury sphygmomanometer measurements, within five mmHg, as well as 96% and 99% agreement, within 10 mmHg and 15 mmHg, respectively (Mattu et al., 2004). The BpTRU cuff was attached to the non-dominant arm of participants.

Measurements were taken every two minutes during the baseline period and the task period (at minute two and minute four), and every minute of 10 minutes during the recovery period. There is no prescribed length of time for the determination of an appropriate recovery period (Linden, Earle, Gerin, & Christenfeld, 1997). Studies have ranged from two minutes to 30 minutes. On average, the majority of participants exposed to laboratory stressors recover within the first two minutes after the termination of the stress task, with the exception of anger provocation, which takes longer (Linden et al., 1997). However, even in an anger-provocation study conducted in our laboratory, group averages in the recovery period no longer significantly differed from baseline by minute four of the recovery period.

I collected data each minute for five minutes, but planned to include the data only up to the reading that differs significantly from baseline. Raw change scores for reactivity data were calculated by subtracting the average of the final two baseline readings from the average of the three reactivity readings. Raw change scores for recovery data were calculated by subtracting the average of the final two baseline readings from the average of the number of readings in the recovery period that are significantly different from baseline.

#### **2.2.4.2 HRV**

HRV was measured using the CardioPro Version 1.0 (Thought Technology; Montreal, Canada) for the ProComp+ system, with three electrodes attached to the chest in standard three-

lead configuration. Measurements were taken continuously during the baseline period (10 minutes), but only the second five-minute interval was assessed. The five-minute interval was chosen in accordance with standardized recommendations for the length of short-term assessments (Task Force of the European Society of Cardiology and The North American Society of Pacing and Electrophysiology, 1996). Changes in HRV were not measured during the course of the experiment due to poor reliability in the measurement of HRV under stress conditions such as the cold pressor task (Sandercock, Bromley, & Brodie, 2005).

Frequency domain methods and time domain methods represent two methods to assess HRV, but only frequency methods are recommended for short-term recording procedures (Task Force of the European Society of Cardiology and The North American Society of Pacing and Electrophysiology, 1996), and are therefore the methods of choice in this study. Frequency domain methods attempt to uncover the source of the variability, derived through fast Fourier transformation and spectral analysis of the electrocardiogram (ECG) recordings. Commonly studied intercorrelated components include HF, LF, and very low frequency (VLF) (Task Force of the European Society of Cardiology and The North American Society of Pacing and Electrophysiology, 1996). These components allow for determination of the variation (also known as power) at different frequencies, distinguishing between the relative contributions in power from the PNS and SNS (Terathongkum & Pickler, 2004). The source of variation of VLF is poorly understood and is not recommended in short-term measurement periods, and there is considerable controversy over whether the LF component is a marker of sympathetic tone or is influenced by both the sympathetic and vagal activations. The HF component is the best understood and is used in this study. It is found between 0.15 and 0.4 Hz, and is driven by respiration and associated with the PNS. HF power was measured in normalized units.

Normalized units represent the relative value of the HF power component in proportion to the total power minus the power of the VLF component, which emphasizes the balance of the sympathetic and parasympathetic nervous systems (Task Force of the European Society of Cardiology and The North American Society of Pacing and Electrophysiology, 1996).

A review conducted by Sandercock, Bromley, and Brodie (2005) concludes that under resting conditions, in healthy participants, the majority of studies suggest that HRV is a moderately reliable measurement. Average-high intraclass correlations have been reported in both frequency and time domain measures between measurement period over two days (Marks & Lightfoot, 1999).

#### **2.2.4.3 Respiration activity**

Respiration rate was recorded with the CardioPro Version 1.0 (Thought Technology; Montreal, Canada) for the ProComp+ system using a PS-I strain gauge filled with conduction fluid. The strain gauge was attached by Velcro strap at the level of the umbilicus to measure abdominal breathing rate. Inhalation causes the tube to stretch, while exhalation causes the tube to retract. The change in voltage across the tube can be measured within a range of 0-100 units of relative strength. Sample respiration rate was taken continuously throughout the baseline period (10 minutes) and average breaths per minute was recorded. Test-retest reliability is moderately high (Gevirtz & Schwartz, 2003).

#### **2.2.5 Waist circumference**

Waist circumference was measured in this study, because it has been identified as the best single anthropometric measure to identify individuals at risk for cardiovascular disease (Dobbelsteyn, Joffres, MacLean, & Flowerdew, 2001). Waist circumference was measured in

accordance with the Canadian Society for Exercise Physiology (CSEP; 2003), using a fabric measuring tape. Participants were asked to stand erect with arms hanging relaxed at the sides, while the research assistant placed the measuring tape horizontally mid-way between the bottom of the rib cage and the iliac crest, and applied tension to the tape without causing indentation of the skin. Measurements were taken at the end of a normal exhalation, and rounded to the nearest 0.5 cm.

### **2.2.6 Aerobic fitness**

Aerobic fitness was measured using the modified Canadian Aerobic Fitness Test (mCAFT), a submaximal (85% of maximum HR) protocol to determine aerobic fitness (CSEP, 2003). In this test, participants were first fitted with a portable HR monitor (Polar FS2c), lead through mild calf stretching, and briefly trained on how to perform the required task. Participants completed a minimum of one and a maximum of six three-minute sessions of stepping on a two-step (each 20.3 cm) bench at predetermined speeds based on age and gender, guided by audio instructions. At the end of each three-minute session, the research assistant checked whether the participant's HR had reached or exceeded their predicted 85% maximal HR based on age and gender. If the participant had not reached this value, a further three-minute session was performed, at a faster cadence.

The mCAFT presents risks to participants that are associated with general exercise. These include possible dizziness, breathlessness or fainting. In the case of an unexpected emergency, research assistants obtained training in basic CPR, and were instructed to call 911. Research assistants were trained to stop the task in the case of dizziness, nausea, any heart symptoms, severe fatigue, breathlessness, feeling of faint, leg cramps or palor, or at any request by the

participant. In five cases (two sedentary participants, two yogis, and one runner), participants asked to stop and the test was terminated.

Once completed, participants were instructed to walk slowly in the corridor for two minutes, and then to sit down. BP and HR were checked before participants left the laboratory to ensure that SBP was less than 145 mmHG, DBP was less than 95 mmHG, and HR was less than 100 beats/minute.

Aerobic fitness score was established using the following equation:  $10 \times [17.2 + (1.29 \times \text{O}_2\text{cost}) - (0.09 \times \text{wt. in kg}) - (0.18 \times \text{age in years})]$ , whereby the  $\text{O}_2$  cost is derived in accordance with the stage completed to reach 85% maximal HR. Aerobic fitness zone (Excellent, Very good, Good, Fair, Needs improvement) was derived from the aerobic fitness score, which accounts for gender and age.

### **2.2.7 Laboratory stress induction**

To induce somatic stress, I used the isometric handgrip task in which participants are instructed to maintain handgrip tension on a standard dynamometer at 20% maximum for three minutes followed by two minutes at 30% maximum. To induce cognitive stress, I used a mental arithmetic task, in which 30 equations were presented on a computer screen, for 10 seconds each, for a total of five minutes. The equations were either addition, subtraction, multiplication, or division. Participants were instructed to compute their answers mentally, and to write their answers on a sheet marked one to 30. The task has been previously shown to raise SBP and DBP by approximately 10 mmHG and to raise HR by approximately 10 beats per minute (Linden, 1991).



### **2.2.8 Socioeconomic status**

The widely used Four Factor Index of Social Status (Hollingshead, 1975) was used to measure socioeconomic status (SES). The measure is based on educational and occupational attainment, applying more weight to occupation using a ratio of five to three. In non-student adults, the score is based on educational and occupational attainment averaged between participants and their spouses, if married, or based solely on the participants' attainment, if unmarried. In children and students, the score is based on the attainment of their parents. Unfortunately, the questions of spousal education and occupation were incorrectly missing in the present study, and therefore, only parental SES could be calculated. Parental SES was appropriate for students in the study, but was not ideal for the non-students.

## **2.3 Procedure**

The study took place in the Behavioural Cardiology Laboratory in the Kenny Building located on the campus of the University of British Columbia from March 19<sup>th</sup>, 2010 to October 3<sup>rd</sup>, 2010. Participants were asked, prior to arrival at the lab, to abstain from consuming caffeine or alcohol, and to abstain from meditation, yoga, running or vigorous exercise for the 12 hours prior to participation. The study protocol lasted between two and two and a half hours and is described below:

1. The participant completed the consent form, followed by the battery of psychological questionnaires (BDI, AQ, PSS-10, STICSA-T, ISEL, MAAS) and three lifestyle questionnaires (vegetarianism self-report questionnaire, DUF, PSQI). Completion took 30-60 minutes, depending on the participant's speed. A bathroom break was offered.

2. The research assistant measured weight, waist circumference, and handgrip strength. The standard occlusion cuff, electrodes and strain gauges were attached to the participant.
3. The baseline measurement period began and the participant completed the STICSA-S for the first time. Measurements were taken every two minutes for 10 minutes.
4. The participant was exposed to one of two counter-balanced five-minute laboratory stressors, following one minute of instruction. Readings were taken every two minutes.
5. After the termination of the stressor, the recovery period began. The participant completed the STICSA-S for the second time. Measurements were taken every minute for five minutes, followed by one minute of rest.
6. The second baseline period began and the participant completed the STICSA-S for the third time. Measurements were taken every two minutes at minute two and minute four. These measurements were averaged to compute the baseline period for the second stressor.
7. The participant was exposed to the second five-minute laboratory stressor, after one minute of instruction. Measurements were taken every two minutes.
8. After the termination of the stressor, the recovery period began. The participant completed the STICSA-S for the fourth time. Measurements were taken every minute for four minutes.
9. The cuff, electrodes, and strain gauge were removed. A bathroom break was offered.
10. A portable HR monitor was attached across the participant's chest. The participant completed the mCaft (with mild calf stretching before and after). BP and HR were verified for safety before detaching the HR monitor.
11. The participant was debriefed, questions were answered, and an honorarium was given.

## **2.4 Data analysis**

Statistical analyses were conducted using SPSS version 17.0 for Windows. Group differences were analyzed by analysis of variance (ANOVA) and, when appropriate, by multivariate analysis of variance (MANOVA), when dependent variables were continuous. Analysis of covariance (ANCOVA) and multivariate analysis of covariance (MANCOVA) were used when it was necessary to control for additional variables (e.g., age). Binary logistic regression was used to analyze group differences on dichotomous dependent variables (e.g., vegetarian versus non-vegetarian, cigarette smoker versus non-smoker, marijuana user versus non-user) and multinomial logistic regression was used to analyze group differences on categorical variables with more than two levels (e.g., alcohol consumption, caffeine consumption).

In cases where there was a significant group difference between yogis and sedentary individuals on a physiological marker of cardiovascular health (i.e., BP and HR at rest and in response to stressors, and HRV at rest), hierarchical linear regression was used to detect significant mediators between group membership and the dependent variables, using the logic of Baron and Kenny (1986). The Sobel test (1982) was used to test the significance of relevant indirect effects.

## **2.5 Power analysis**

To determine the adequate sample size necessary to detect group differences of interest, power estimation analyses were conducted using G\*Power (Faul, Erdfelder, Buchner, & Lang, 2009). Because there were no available studies using this design, the power analysis could not be based on an estimate of expected effect size. Instead, clinical significance of differences between

groups was used, whereby it has been demonstrated that a reduction of 5 mmHG in DBP corresponds to a 20% reduction in risk of hypertension several years later in both hypertensives and normotensives (Collins et al., 1990). Average DBP in the present study's sedentary group was expected to approximate those of individuals included in a previous study conducted in our lab that included residents of Vancouver and surrounding areas who were normotensive, did not take antihypertensive medication, and were of similar age range, ethnicity, and gender ratio (Moseley & Linden, 2006). The previous sample's mean DBP was 67.0 ( $SD = 9.2$ ). A 5 mmHG difference between the sedentary group in our study, set at 67.0 ( $SD = 9.2$ ), and either the group of runners or yogis yielded a moderate effect size of  $f = .26$ . When using ANOVA, with a power of .8 and alpha of .05, I would require 146 participants to detect this moderate effect size of group membership on DBP.

The moderate effect size used in this power analysis was reasonable to expect from the limited evidence existing to date. In a cross-sectional study of practitioners of yoga including asana practice, resting DBP differed significantly between yogis and sedentary controls, yielding a large effect size,  $d = -0.99$  (Bharshankar, Bharshankar, Deshpande, Kaore, & Gosavi, 2003).

In the regression analyses, which exclude the running group, a ratio of 10:1 participants to predictors would allow for up to nine predictor variables in the model while maintaining the stability of the coefficients.

### **3 Results**

#### **3.1 Data inspection, assumption testing, and reducing type I error**

##### **3.1.1 Data inspection**

Participant data were entered into SPSS 17.0 twice independently by two research assistants. In conjunction with a research assistant, I identified data entry errors by comparing the two data files, as well as by examining the minimum and maximum scores and the mean scores of continuous data. We resolved these errors through the examination of the original data and through consensus when data were ambiguous. We visually inspected each participant's HRV data to identify technical errors. Errors can occur when electrostatic noise or electrical activity from muscle groups interferes with the EKG recording, causing an erroneous extra heart beat, or a missed heart beat. We corrected errors by adding or splitting inter beat interval values, according to guidelines of the Cardiopro, Version 1.0 User's Manual (Thought Technology, Montreal).

##### **3.1.2 Statistical assumption testing**

The assumptions of ANOVA, MANOVA, and regression were tested, and violations were addressed when identified. For ANOVA, assumptions are independence, normality, and homoscedasticity. Given that the independent variable of interest in the analyses in this study was group membership (yoga, running, sedentary), there was no reason to suspect that the assumption of independence was violated as all participants were independent from one another. Additionally, the study took place over a short period of time, and no seasonal effect is suspected. Normality of the sampling distributions was examined using visual inspection of histograms, and reasonably normal distributions were considered normal. When in question, normal quantile-

quantile (Q-Q) plots were also inspected for relatively straight lines. Outliers were identified by examining boxplots, and the 5% trimmed mean scores were compared to the total mean to assess the influence of outliers on the mean. HF, a HRV measure, appeared positively skewed, and the data were natural log transformed ( $\ln$ ), which is commonly performed to normalize HRV data (e.g., Lobnig, Maslowska-Wessel, & Bender, 2003; Tsuji et al., 1994). After this transformation,  $\ln$ HF power appeared normal. Measures of change in state anxiety were also identified as problematic. Outliers (three standard deviations above the mean) were excluded from these variables, because they changed the significance of results in some cases, and the distribution appeared reasonably normal after their removal. All other variables analyzed by ANOVA were included without any changes. Homoscedasticity was assessed with Levene's test. Given that Levene's test is very conservative, data were evaluated at  $\alpha = .001$ , and no violations were identified, with the exception of waist circumference,  $F(2,142) = 8.64, p < .001$ .

For MANOVA, assumptions of linearity, absence of multicollinearity, multivariate normality, and homogeneity of variances and covariances were tested. It was always the case that the number of participants per cell was greater than the number of dependent variables, thus MANOVA values can be trusted as accurate. MANOVA was used to assess group differences on psychological variables. The assumption of linearity held based on significant bivariate correlations between all variables. Correlations for perceived stress, anxiety, and depression, were in the .7 range, indicating risk of multicollinearity. Perceived stress was removed for its redundancy with anxiety, but depression and anxiety were both analyzed, because the two variables are known to be distinct yet related in the literature and are thus treated as such herein. Given that this violation results in a reduction in statistical power, the potential for conservative bias was accepted in this case.

To assess multivariate normality, Mahalanobis' distance was used to identify multivariate outliers which impact normality, with alpha set at .001. No violations of multivariate normality were found for multivariate analysis of group differences in psychological variables. Box's M Test of Equality of Covariance Matrices was used to examine multivariate normality. Because the test is very sensitive, the accepted alpha level was set at .001, and there were no violations. To assess homogeneity of variances, Levene's Test of Equality of Error Variances was used, and did not indicate violations at the .001 alpha level.

MANOVA was also used to assess group differences in BP recovery (including SBP and DBP) from the arithmetic task, BP recovery from the handgrip task, and BP recovery averaged across tasks. The assumption of linearity held based on significant bivariate correlations between each pair of BP measures. Multicollinearity was absent. One violation of multivariate normality was found for each of the multivariate analyses of group difference in BP recovery (i.e., average SBP and DBP recovery, arithmetic SBP and DBP recovery, handgrip SBP and DBP recovery) and these cases were excluded from the multivariate analysis. Box's M Test of Equality of Covariance Matrices did not identify violations of multivariate normality. Levene's Test of Equality of Error Variances did not indicate violations of homogeneity of variances.

For linear regression, the assumptions of linearity, independence, homoscedasticity, and normality were tested. To assess linearity, plots for residuals versus predicted values were observed, and no significant deviations from linearity were found. To assess independence, the Durbin-Watson statistic was examined for values below 1.4 and above 2.6, and independence was not violated. To assess homoscedasticity, scatterplots of the residuals versus predicted values were examined for their spread. The spread was evenly dispersed for all variables. To assess normality, normal probability plots of the residuals versus predicted values were examined, and

normality was not violated.

Lifestyle factors including cigarette smoking, drug use, alcohol consumption, caffeine consumption, and meat-eating did not have normal distributions, often displaying multiple modes or a mode of the minimum value. These variables were reclassified categorically and group differences were assessed with binary logistic regression or multinomial logistic regression. Assumptions were satisfied given that observations were presumed to be independent, and that the observation to predictor ratio was greater than 10 to one (Peng, Lee, & Ingersoll, 2002).

### **3.1.3 Reducing type I error**

Because there are a large number of analyses in this study, care was taken to reduce type I error in several ways: 1) MANOVA was chosen over separate ANOVAs when the assumptions of MANOVA were met, 2) the conservative Scheffé's post-hoc test was chosen to identify significant group differences when ANOVAs were significant, 3) Bonferroni correction with a family-wise alpha of .1 was utilized when performing multiple analyses on the same set of data.

## **3.2 Participants**

### **3.2.1 Recruitment**

Recruitment sources are described in Figure 2, by group. Of the total number of individuals who expressed interest in participating in the study ( $N = 348$ ), 32% of individuals responded to an advertisement on the Craigslist Vancouver website. Thirty-two percent of individuals responded to a posted or print advertisement. Sixteen percent of individuals were referred by word of mouth. Twenty percent of individuals were referred by unknown sources, either because they did not remember the source or because we were unable to reach them after their initial communication.



### **3.2.2 Eligibility screening procedure**

Figure 2 depicts the number of individuals who expressed interest in participating, their referral source and the reasons for exclusions, by group. Of the 348 individuals who contacted the lab by email or telephone to indicate interest in participating in the study, 131 identified as yogis, 119 identified as runners, and 98 identified as sedentary. Of these individuals, 302 were interviewed using a telephone screening protocol, while 46 were unavailable for a telephone screen. Reasons for exclusion included medical problems, age (below 20 or above 59), and overly frequent participation in physical activity. In the yoga and running groups other reasons for exclusion included irregular yoga practice or running practice and regular participation in other physical activity. Of the individuals who were eligible, 13% were unable to participate due to scheduling conflicts.

Nine individuals were determined to be eligible by telephone screen and therefore participated in the study, but were ultimately excluded. Although they had reported sufficient participation in yoga or running (three times per week, 30 minutes each session, for two years) in the telephone interview, they reported insufficient total minutes per week, times per week, or years of experience in the self-report questionnaire completed in the laboratory (Yoga  $n = 4$ , Running  $n = 5$ ). Cases in which individuals reported “2-3” times of participation per week with total minutes of participation per week of greater than or equal to 90 were retained in the sample (Yoga  $n = 2$ , Running  $n = 1$ ). A total of 145 individuals were included in the study (Yoga  $n = 47$ , Running  $n = 46$ , Sedentary  $n = 52$ ).

### 3.3 Sample characteristics

#### 3.3.1 Assessment of demographic equivalence

A description of demographic variables by group is located in Table 1. By one-way Analysis of Variance (ANOVA), a significant group difference was found for age,  $F(2,142) = 4.88, p = .03$ . Post-hoc analysis (Scheffé) revealed that the group difference was accounted for by yogis' older age compared to runners' age,  $p = .04$  (See Table 1 for descriptive statistics). The Chi-square test of independence was used to determine that groups did not differ significantly by gender,  $\chi^2(2) = .01, p = .99$ .

Differences were present for race/ethnicity, when dividing the sample into individuals who identified themselves as White (65%) and as Asian including South Asian (28%), which together represented the majority of the sample (93%). Seven percent of participants identified with other ethnicities: African ( $n = 3$ ), First Nations ( $n = 4$ ), Hispanic ( $n = 1$ ), and Middle Eastern ( $n = 1$ ). When comparing White and Asian race/ethnicity by group using a chi-square test, the groups differed significantly,  $\chi^2(2) = 11.97, p < .01$ . Yogis and sedentary individuals differed,  $\chi^2(1) = 11.54, p < .001$ , whereby the yogis were comprised of less Asian individuals, and more White individuals than the sedentary group. Runners and sedentary individuals did not differ,  $\chi^2(1) = 3.52, p = .06$ , nor did yogis and runners,  $\chi^2(1) = 2.53, p = .11$ . Due to differences between groups, age and ethnicity were controlled for in subsequent analyses, when appropriate.

Of the total sample, 51% identified as non-religious. The groups did not differ in identifying as non-religious versus identifying with a religion,  $\chi^2(2) = 4.19, p = .12$ . The most commonly reported religions were Christianity (26%) and Buddhism (11%). Participants who self-identified as Christian were unevenly distributed between the groups, Yates'  $\chi^2(2) = 8.57, p = .01$ , whereby more sedentary participants identified as Christian compared to the yoga group.

There was a marginally significant difference between groups in identifying as Buddhist, Yates'  $\chi^2(2) = 5.8, p = .05$ , whereby the yoga group had a greater proportion of Buddhists compared to the running group. Descriptive statistics are provided for all religions by group and in the total sample in Table 1.

Group differences in marital status were analyzed in terms of partnered (including those who are married, common law partnered, or in stable relationships) or single (including those who are divorced, separated, widowed, or never married and single). There was a marginally significant difference between groups on marital status,  $\chi^2(2) = 6.15, p = .05$ . A significantly higher proportion of runners were partnered compared to yogis,  $\chi^2(1) = 4.73, p = .03$  and to sedentary individuals,  $\chi^2(1) = 4.46, p = .03$ . Yogis and sedentary individuals did not differ on marital status,  $\chi^2(1) = .01, p = .91$ .

A one-way between-group ANOVA revealed that student status was not significantly different by group,  $\chi^2(2) = 4.78, p = .09$ . A one-way between-group ANOVA revealed that parental SES did not differ between groups,  $F(2,134) = 2.92, p = .06$ . Note that higher scores represent lower SES.

### **3.3.2 Descriptions of yoga and running groups**

#### **3.3.2.1 Yoga group**

Table 2 describes the yoga practices of the yoga group including frequency of asana practice and meditation practice, history of practice, style of practice, breathing practice and goals of practice. The yoga group was comprised of individuals with large variability in yoga practice and experience. They had been practicing yoga regularly for a mean of 6.49 years with a standard deviation (*SD*) of 3.67, ranging from 2 to 18 years. They reported practicing yoga a

mean of 5.1 times per week ( $SD = 4.12$ ), ranging from 2.5 to 30 times per week. Two participants indicated they practiced two to three times per week in the questionnaire, although they had indicated a minimum of three times per week in telephone interview. The yoga group reported a mean of 277.45 minutes per week of yoga including asana ( $SD = 153.97$ ), ranging from 90 to 840 minutes per week. The yoga group indicated practicing meditation, accompanying and independent of their yoga practice, a mean of 127.21 minutes per week ( $SD = 215.51$ ), ranging from 0-1260 minutes. Seventy percent of the yoga group practice Ujjayi breathing. This breathing technique involves inhaling and exhaling through the nose, while constricting the throat, which produces a hissing sound. Participants indicated that they practiced other breathing techniques a mean of 6.9 times per week ( $SD = 18.73$ ), ranging from 0 to 125 times. Forty-nine percent of the yoga group identified themselves as yoga instructors, whether or not they were currently teaching. Eighty-seven percent reported that yogic philosophy is part of daily life.

The yoga group practiced a variety of yoga styles. Although ‘Hatha’ refers to yoga asana in general, the North American use of the word denotes a gentle type of yoga. Twenty percent endorsed practicing Hatha yoga, followed by Ashtanga (15%) and Power (15%), which are more vigorous styles. Other styles included Flow/Vinyasa Flow, which is also vigorous, and Iyengar, Yin, and Restorative, which tend to be less vigorous.

Yogis endorsed a range of goals for practicing yoga, as can be seen in Table 3. Improving overall health was the most commonly endorsed goal (96%) and the goal reported as most important (40%). The next most commonly endorsed goals were improving mood (87%) and decreasing tension (83%). In the ‘Other’ category, yogis added many idiosyncratic goals including goals of decreasing anxiety (e.g., “maintain ease”, “mental stillness”, “reduce stress”), yoga promotion (e.g., “yoga advocate”, “share with others”), positive emotion (e.g., “feel young

and alive”, “fun”), other health reasons (e.g., “back health”, “core strength”, “nervous system development”), and others (e.g., “silence”, “improve awareness”, “non-dualist perception”, “better self”).

### **3.3.3.2 Running group**

Table 4 describes the running practices of the running group including frequency of running, length of running history, participation in marathons and half-marathons, and goals of running. The running group reported running regularly for a mean of 8.3 years ( $SD = 6.99$ ), ranging from 2 to 43 years. They reported running a mean of 3.96 times per week ( $SD = 1.18$ ), ranging from 2.5-8 times per week. They had all endorsed running a minimum of three times per week in the telephone interview, but one running participant endorsed two to three times per week by questionnaire. Runners reported running for 218.8 minutes per week ( $SD = 116.4$ ), ranging from 90-600 minutes per week. Fifty-six percent of the running group had participated in a marathon or half-marathon in the previous two years. Of these runners, 39% considered the goal of marathon participation to be competitive.

Runners endorsed a range of goals for running, as can be seen in Table 3. Improving overall health was the most commonly endorsed goal (100%) and the goal reported as most important (46%). The next most commonly endorsed goals were a sense of challenge/accomplishment (83%) and improving appearance (80%). In the ‘Other’ category, runners added “improve digestion” ( $n = 2$ ), “joy of competition” ( $n = 1$ ), “connect with nature” ( $n = 1$ ), and “transportation” ( $n = 1$ ).

### **3.4 Baseline physiological variables**

Descriptive statistics for physiological variables are provided in Table 5, and correlations between them are provided in Table 6. Separate ANOVAs were run for SBP, DBP, and HR. Resting systolic BP (SBP) and diastolic BP (DBP) correlated,  $r(141) = .87, p < .01$ , and this high level of correlation violates the assumption of absence of multicollinearity required for MANOVA. Rather than choosing only one BP measure, both were analyzed, because they were of primary interest in the study and are distinctly meaningful physiologically.

#### **3.4.1 SBP**

##### **3.4.1.1 Demographic confounding variables**

Race/ethnicity, divided into White and Asian, was not related to SBP,  $F(1,131) = 1.5, p = .22$ . Age was found to predict SBP in linear regression,  $\beta = .37, t(141) = 4.74, p < .001$ . Age explained a significant proportion of variance in SBP,  $R^2 = .14, F(1,141) = 22.42, p < .001$ . Age was therefore entered as a covariate for BP.

##### **3.4.1.2 Group and gender differences**

With age entered as a covariate, and group and gender entered as fixed factors, gender was associated with SBP by two-way ANCOVA,  $F(1,136) = 21.77, p < .001$ , whereby males had higher SBP than females. Gender did not interact with group membership on SBP,  $F(2,136) = .11, p = .9$ . No group differences were found for SBP,  $F(2,136) = 2.35, p = .1$ . See Table 5 for descriptive statistics.

### **3.4.2 DBP**

#### **3.4.2.1 Demographic confounding variables**

Race/ethnicity, divided into White and Asian was not related to DBP,  $F(1,131) = 2.03, p = .16$ . Race/ethnicity was subsequently left out of analyses. Age predicted DBP,  $\beta = .31, t(141) = 3.9, p < .001$ , and explained a significant proportion of variance in DBP,  $R^2 = .1, F(1,141) = 15.24, p < .001$ . Age was therefore entered as a covariate for DBP.

#### **3.4.2.2 Group and gender differences**

With age entered as a covariate, and group and gender entered as fixed factors, gender was associated with DBP by two-way ANCOVA,  $F(1,136) = 10.9, p = .001$ , whereby males had higher DBP than females. Gender did not interact with group membership on BP,  $F(2,136) = .01, p = .99$ . No group differences were found for DBP,  $F(2,136) = .5, p = .61$ .

### **3.4.3 HR**

#### **3.4.3.1 Demographic confounding variables**

Race/ethnicity was not significantly related to HR,  $F(1,131) = 2.15, p = .15$ . Age did not predict HR,  $\beta = -.14, t(141) = -1.7, p = .09, R^2 = .02, F(1,141) = 2.9, p = .09$ .

#### **3.4.3.2 Group and gender differences**

Gender was not related to HR,  $F(1,137) = 2.96, p = .09$ , nor did it interact with group membership,  $F(2,137) = .59, p = .56$ . A significant group difference was found for resting HR,  $F(2,137) = 15.45, p < .001$ . Post-hoc analyses (Scheffé) revealed that yogis had significantly lower resting HR than sedentary individuals,  $p < .01$ , runners had significantly lower resting HR than sedentary individuals,  $p < .001$ , and yogis and runners did not significantly differ from each other,  $p = .16$ .

### **3.4.4 Respiration rate**

Respiration rate was not correlated with heart rate in this sample,  $r(137) = .05$ ,  $p = .56$ , and was analyzed separately.

#### **3.4.4.1 Demographic confounding variables**

Race/ethnicity was not related to respiration rate,  $F(1,123) = 2.14$ ,  $p = .15$ , nor was age,  $\beta = .10$ ,  $t(137) = -1.12$ ,  $p = .27$ ,  $R^2 = .01$ ,  $F(1,137) = 1.24$ ,  $p = .27$ , and were subsequently left out of analyses.

#### **3.4.4.2 Group and gender differences**

No significant gender difference existed in respiration rate,  $F(1,133) = .11$ ,  $p = .74$ . There was no interaction between gender and group membership,  $F(2,133) = 1.59$ ,  $p = .21$ . There was a significant group difference in respiration rate,  $F(2,133) = 5.66$ ,  $p < .01$ . Post-hoc (Scheffé) tests revealed that yogis had significantly lower respiration rate than sedentary individuals,  $p < .01$ , but did not differ from runners,  $p = .14$ . Runners and sedentary individuals did not differ on respiration rate,  $p = .4$ . When only yogis who practiced Ujjayi breathing (70% of the yoga sample) were included, the overall group difference strengthened,  $F(2,122) = 7.36$ ,  $p = .001$ . Yogis who practiced Ujjayi demonstrated marginally significantly fewer breaths per minute ( $M = 12.11$ ,  $SD = 2.48$ ) compared to runners,  $p = .05$ , and significantly fewer breaths per minute compared to sedentary individuals,  $p = .001$ .

### **3.4.5 HRV**

ANCOVA was used to analyze group differences on lnHF power, a frequency domain HRV measure, covarying for respiration rate, which significantly predicted lnHF power,  $\beta = -.33$ ,  $t(133) = -3.7$ ,  $p < .001$ ,  $R^2 = .11$ ,  $F(1,133) = 16.1$ ,  $p < .001$ .



### **3.4.5.1 Demographic confounding variables**

When covarying for respiration rate, race/ethnicity was related to HF power,  $F(1,122) = 8.07, p = .01$ , whereby White participants had higher HF power ( $M = 850.39, SD = 815.65$ ) compared to Asian participants ( $M = 356.9, SD = 379.2$ ). A regression analysis showed that age contributed to variance in lnHF power over and above respiration rate,  $\beta = -.29, t(132) = -3.7, p < .001, R^2 \text{ change} = .08, F(1,132) = 13.67, p < .001$ .

### **3.4.5.2 Group and gender differences**

When age and respiration rate were entered as covariates, with race/ethnicity and group as fixed factors, gender was not related to lnHF power by three-way ANCOVA,  $F(1,111) = 1.17, p = .28$  and gender did not interact with group,  $F(2,111) = .71, p = .5$ . There was a significant group difference on lnHF power,  $F(2, 111) = 4.15, p = .02$ . Correcting for multiple comparisons (the corrected alpha was  $p = .03$ ), sedentary individuals had significantly lower lnHF compared to yogis,  $p = .02$ , and compared to runners,  $p = .02$ . Yogis and runners did not significantly differ,  $p = .74$ .

## **3.5 Baseline psychological variables**

The psychological variables included depression, hostility, trait anxiety, social support, mindfulness. Each of the baseline psychological variables of interest correlated with each other (See Table 7), and were therefore analyzed together in subsequent analyses using MANOVA to reduce type I error. Means and standard deviations of the psychological variables by group are located in Table 5.

### 3.5.1 Demographic confounding variables

Race/ethnicity was not significantly related to psychological variables, Wilks'  $\Lambda = .93$ ,  $F(5,124) = 2.0$ ,  $p = .08$ . Age was significantly associated with the psychological variables, Wilks'  $\Lambda = .89$ ,  $F(5,129) = 3.08$ ,  $p = .01$ , driven by greater mindfulness associated with older age,  $F(1,140) = .79$ ,  $p = .01$ .

### 3.5.2 Group and gender differences

When age was entered as a covariate, there was no significant gender difference for the combined psychological variables by MANCOVA, Wilks'  $\Lambda = .95$ ,  $F(5,129) = 1.29$ ,  $p = .27$ . There were significant group differences when considering these psychological variables together, Wilks'  $\Lambda = .72$ ,  $F(10, 258) = 4.68$ ,  $p < .001$ , with no significant interaction between gender and group, Wilks'  $\Lambda = .93$ ,  $F(10, 258) = .89$ ,  $p = .54$ .

Simple contrasts examined specific group differences on the psychological variables, while controlling for age and race/ethnicity. The corrected alpha was .007. On depression, yogis and runners scored significantly lower than sedentary individuals,  $p < .001$  and  $p = .001$ , respectively, but yogis and runners did not differ from each other,  $p = .77$  (see Table 5 for descriptive statistics). On trait anxiety, yogis and runners scored significantly lower than sedentary individuals, both at  $p < .001$ , but did not differ from each other,  $p = .67$ . On hostility, yogis and runners scored significantly lower than sedentary individuals,  $p < .007$  and  $p = .007$ , respectively. Yogis did not differ from runners on hostility,  $p = .85$ . On social support, runners scored significantly higher than sedentary individuals,  $p < .001$ , but did not significantly differ from yogis,  $p = .1$ . Yogis and sedentary individuals did not differ on social support using the corrected alpha of .007,  $p = .02$ . Being partnered versus single was associated with greater

reported social support  $F(1,141) = 13.83, p < .001$ , and was subsequently added as a fixed factor. Marital status did not interact with group membership on social support,  $F(1,126) = 1.56, p = .21$ . The difference between runners and sedentary individuals remained with marital status added,  $p = .001$ .

Finally, there were no significant group differences on mindfulness using the corrected alpha. The effect size was  $\eta^2 = .04$ . Yogis did not differ from runners,  $p = .04$ , or from sedentary individuals,  $p = .04$ . Runners and sedentary individuals did not differ,  $p = .95$ . Length of yoga practice history was examined in the yoga group, and mindfulness was not related to longer history of practice,  $r(47) = .14, p = .36$ .

In sum, yogis and runners did not differ from each other on any psychological variables. Both the yoga group and the running group reported less depression, anxiety, and hostility compared to the sedentary group, and runners reported greater social support compared to sedentary individuals.

### **3.6 Personality**

Personality variables were analyzed separately, although some variables correlated with each other (see Table 8).

#### **3.6.1 Agreeableness**

##### **3.6.1.1 Demographic confounding variables**

Whites scored significantly higher on agreeableness compared to Asians,  $F(1,133) = 6.59, p = .01$ . Older age significantly predicted greater agreeableness,  $\beta = .17, t(143) = 2.01, p < .05, R^2 = .03, F(1,143) = 4.06, p < .05$ .

### **3.6.1.2 Group and gender differences**

Gender was not significantly related to agreeableness,  $F(1,122) = 3.65, p = .06$ , nor was group,  $F(2,122) = 1.54, p = .22$ , and there was no significant group by gender interaction,  $F(2,122) = .94, p = .4$ .

## **3.6.2 Conscientiousness**

### **3.6.2.1 Demographic confounding variables**

White participants scored significantly higher on conscientiousness compared to Asian participants,  $F(1,133) = 4.92, p = .03$ . Older age significantly predicted greater conscientiousness,  $\beta = .19, t(143) = 2.33, p = .02, R^2 = .04, F(1,143) = 5.42, p = .02$ .

### **3.6.2.2 Group and gender differences**

Gender was not significantly related to conscientiousness,  $F(1,122) = .1, p = .76$ , and there was no group by gender interaction,  $F(2,122) = 1.38, p = .26$ . There was, however, a significant group difference,  $F(2,122) = 8.64, p < .001$ .

Simple contrasts reveal that yogis did not differ from runners,  $p = .12$ , or sedentary participants,  $p = .06$  on conscientiousness. Runners scored significantly higher on conscientiousness compared to sedentary individuals,  $p < .001$  (See Table 5 for descriptive statistics).

### **3.6.3 Extraversion**

#### **3.6.3.1 Demographic confounding variables**

Race/ethnicity was not significantly related to extraversion,  $F(1,133) = 2.1, p = .15$ , and age did not predict extraversion,  $\beta = -.14, t(143) = -1.72, p = .09, R^2 = .02, F(1,143) = 2.94, p = .09$ .

#### **3.6.3.2 Group and gender differences**

Gender was significantly related to extraversion,  $F(1,139) = 7.01, p = .01$ , but there was no significant group difference,  $F(2,139) = 1.31, p = .27$ , and no group by gender interaction,  $F(2,139) = 2.49, p = .09$ .

### **3.6.4 Emotional stability**

#### **3.6.4.1 Demographic confounding variables**

White participants scored significantly higher on emotional stability compared to Asian participants,  $F(1,133) = 4.65, p = .03$ . Older age significantly predicted greater emotional stability,  $\beta = .25, t(143) = 3.11, p < .01, R^2 = .06, F(1,143) = 9.7, p < .01$ .

#### **3.6.4.2 Group and gender differences**

Gender was not significantly related to emotional stability,  $F(1,122) = .98, p = .33$ , and there was no main effect of group  $F(2,122) = 2.8, p = .07$ , nor was there a group by gender interaction,  $F(2,122) = .31, p = .74$ .

### **3.6.5 Openness to experience**

#### **3.6.5.1 Demographic confounding variables**

White participants scored significantly higher on openness to experience compared to Asian participants,  $F(1,135) = 7.93, p = .01$ . Age did not significantly predict openness to experience,  $\beta = .1, t(143) = 1.23, p = .22, R^2 = .01, F(1,143) = 1.52, p = .22$

#### **3.6.5.2 Group and gender differences**

Gender was not significantly related to openness to experience,  $F(1,123) = 8.99, p = .01$ , and there was no group by gender interaction,  $F(2,123) = 1.15, p = .32$ . There was no group difference,  $F(2,123) = 2.4, p = .1$ .

### **3.7 Waist circumference**

#### **3.7.1 Demographic confounding variables**

Asian participants had a significantly smaller waist circumference compared to White participants,  $F(1,133) = 8.1, p = .01$ . Older age was significantly related to larger waist circumference,  $\beta = .41, t(143) = 5.44, p < .001, R^2 = .17, F(1,143) = 29.57, p < .001$ .

#### **3.7.2 Group and gender differences**

Age was entered as a covariate, and race/ethnicity as a fixed factor, in the analysis of group differences on waist circumference. Females had significantly smaller waist circumferences compared to males,  $F(1,122) = 14.95, p < .001$ , but no interaction with group membership,  $F(2,122) = .2, p = .82$ . There was also no significant group difference on waist circumference,  $F(2,122) = 2.93, p < .06$ .

### **3.8 Aerobic fitness**

The CSEP-devised aerobic fitness zone scores were used, which account for age and gender.

#### **3.8.1 Demographic confounding variables**

Race/ethnicity was not related to aerobic fitness zone,  $F(1,125) = 1.68, p = .2$ .

#### **3.8.2 Group and gender differences**

Group membership was significantly related to aerobic fitness,  $F(2,134) = 18.97, p < .001$ . Simple contrasts revealed significant group differences between each group, with the corrected alpha of .03. Runners had significantly greater fitness compared to sedentary individuals,  $p < .001$ , and compared to yogis,  $p = .02$ . Yogis had significantly greater fitness than sedentary individuals,  $p = .01$ .

#### **3.8.3 Yoga style**

The yoga participants were divided by their reported yoga style in order to compare the aerobic fitness of those who practice more vigorous yoga styles and those who practice less vigorous yoga styles. Ashtanga, power, Vinyasa flow/flow and sun salutations constituted the more vigorous group ( $n = 15$ ), while restorative, Iyengar, Yin, and meditative yoga constituted the less vigorous group ( $n = 10$ ). Participants who reported other yoga styles were excluded from this analysis, because they are more difficult to categorize. When comparing the two yoga subgroups, there was no difference in aerobic fitness zone,  $F(1,21) = .01, p = .92$ , and no group by gender interaction,  $F(1,21) = .1, p = .76$ .

### **3.9 Lifestyle factors**

Lifestyle factors measured in the study included a continuous measure of sleep, and categorical measures of cigarette smoking status, drug use, caffeine consumption, alcohol consumption, and vegetarianism. Binary logistic regression was used to analyze group differences in cigarette smoking status (smoker versus non-smoker), drug use (marijuana user versus non-user), and vegetarianism (semi-vegetarian/lacto-ovo-vegetarian/vegan versus non-vegetarian). Multinomial logistic regression was used to analyze group differences on caffeine consumption (Less than one cup daily, one and up to three, three and up), and alcohol consumption (tertiles).

#### **3.9.1 Sleep**

##### **3.9.1.1 Demographic confounding variables**

White participants reported poorer global sleep score compared to Asian participants,  $F(1,130) = 4.16, p = .04$  (note that higher scores indicate poorer sleep). Older age significantly predicted worse global sleep,  $\beta = .18, t(140) = 2.13, p = .04, R^2 = .03, F(1,140) = 4.54, p = .04$ .

##### **3.9.1.2 Group and gender differences**

Gender was not related to sleep,  $F(1,119) < .01, p = .96$  and did not interact with group membership,  $F(2,119) = .17, p = .85$ . When including age as a covariate, and including race/ethnicity as a fixed factor, group membership was significantly related to sleep,  $F(2,119) = 7.87, p < .001$ . Runners had significantly better sleep than sedentary individuals,  $p < .001$ , but did not differ from yogis,  $p = .13$  (please see Table 9 for descriptive statistics). Yogis and sedentary individuals did not differ on sleep,  $p = .09$ .



### **3.9.2 Cigarette smoking status**

Cigarette smoking was divided into smoking (coded as 1) and non-smoking status (coded as 0), as there was very little variability in categorizing levels of smoking frequency. There was a very low base rate for smoking, with only 13% of the total sample reporting smoking an average of at least one cigarette per day.

#### **3.9.2.1 Demographic confounding variables**

There was no significant difference observed in smoking status between White participants and Asian participants, Odds Ratio (OR) = 2.22,  $p = .23$ , 95% CI [0.6, 8.18]. Older age was associated with a greater likelihood of smoking cigarettes, OR = 1.05,  $p = .03$ , 95% CI [1.01, 1.1].

#### **3.9.2.2 Group differences**

Controlling for age, yogis were significantly less likely to smoke cigarettes compared to sedentary individuals, OR = 0.03,  $p = .001$ , 95% CI [ $< 0.01$ , 0.25], as were runners compared to sedentary individuals, OR = 0.04,  $p < .01$ , 95% CI [0.01, 0.34]. Yogis and runners did not differ from each other on smoking status, OR = 1.39,  $p = .82$ , 95% CI [0.08, 23.33].

#### **3.9.2.3 Cigarette smoking and physiological variables**

Given the group differences on smoking status, relationships between smoking status and physiological variables were examined. Smoking status was not related to respiration rate,  $F(1,137) = .71$ ,  $p = .4$ , nor to SBP/DBP, Wilks'  $\Lambda = .98$ ,  $F(2,140) = 1.32$ ,  $p = .27$ . It was related to lnHF power,  $F(1,134) = 6.16$ ,  $p = .01$ , and was subsequently included in mediational analysis of the relationship between yoga group membership and higher lnHF power compared to the sedentary group in section 3.13.2.

### **3.9.3 Drug use**

With the exception of marijuana, no participant endorsed using any drug in the past three months (including tranquilizers, amphetamines, barbiturates, heroine, synthetic narcotics, or “other narcotics”). Table 9 provides descriptive statistics on marijuana use under the following categories: never in the past three months, once or twice in the past three months, several times in the past month, several times in the past week, and daily. Because of limited variability, marijuana use was categorized into users and non-users to assess group differences.

#### **3.9.3.1 Demographic confounding variables**

Significantly more White participants reported marijuana use compared to Asian participants,  $OR = 3.92, p = .08, 95\% CI [1.28, 12.06]$ . Age was not associated with marijuana use,  $OR = 1.47, p = .53, 95\% CI [0.96, 1.02]$ .

#### **3.9.3.2 Group differences**

When ethnicity was controlled, there were no group differences. The sedentary group did not differ from the yoga group,  $OR = 0.7, p = .48, 95\% CI [0.26, 1.87]$ , or from the running group,  $OR = 0.58, p = .31, 95\% CI [0.2, 1.67]$ , and the yoga and running groups did not differ,  $OR = 0.58, p = .1, 95\% CI [0.2, 1.67]$ .

### **3.9.4 Vegetarianism**

Dietary practices were assessed in terms of number of meals containing meat per week, as well as categorical data about whether participants were vegans, lacto-ovo vegetarians, semi-vegetarians (consume fish and seafood), or non-vegetarians. When assessed continuously, the data did not follow a normal distribution, as it was multimodal. Vegetarianism was therefore categorized in terms of non-vegetarian (coded as 0) and vegetarian (coded as 1) including vegans,

lacto-ovo vegetarians, and semi-vegetarians. Eighteen percent of the total sample identified as vegetarian according to this criterion. Data on the number of meals containing meat and the categorical data are presented in Table 9.

#### **3.9.4.1 Demographic confounding variables**

There was no significant difference in vegetarianism between White participants and Asian participants,  $OR = 0.31, p = .07$ , 95% CI [0.09, 1.12], Age was not significantly associated with vegetarianism,  $OR = 0.98, p = .2$ , 95% CI [0.9, 1.01].

#### **3.9.4.2 Group differences**

Significantly more yogis were vegetarian compared to runners,  $OR = 5.09, p < .01$ , 95% CI [1.7, 15.28], and compared to sedentary individuals,  $OR = 10.14, p = .001$ , 95% CI [2.75, 37.4). Runners did not differ from sedentary individuals on the likelihood of being vegetarian,  $OR = 0.5, p = .37$ , 95% CI [0.11, 2.23].

### **3.9.5 Caffeine consumption**

Caffeine as a continuous measure yielded a positively skewed and multimodal distribution. It was therefore divided into three categories, reflecting average daily consumption of caffeinated beverages. Less than one daily cup of a caffeinated beverage (absent) was coded as 0, one and up to 3 (moderate) was coded as 1, and three and up (high) was coded as 2. Table 9 provides descriptive statistics.

#### **3.9.5.1 Demographic confounding variables**

White participants reported significantly higher caffeine consumption compared to Asian participants. Compared to Asian participants, White participants were more likely to be high

consumers than to be moderate consumers,  $OR = 4.16, p = .02, 95\% CI [1.29, 13.39]$ , and more likely to be high consumers than to abstain from drinking caffeine,  $OR = 8.29, p = .001, 95\% CI [2.45, 28.05]$ . As age increased, so did the probability of being a high caffeine consumer compared to a moderate consumer,  $OR = 1.09, p < .001, 95\% CI [1.05, 1.14]$ , and of being a high caffeine consumer compared to a caffeine abstainer,  $OR = 1.12, p < .001, 95\% CI [1.06, 1.17]$ .

### **3.9.5.2 Group differences**

When controlling for ethnicity and age, the only group difference was that runners were less likely than sedentary individuals to be high consumers of caffeine relative to the likelihood of being moderate consumers,  $OR = 0.29, p = .04, 95\% CI [0.09, 0.94]$ .

## **3.9.6 Alcohol consumption**

Alcohol as a continuous measure yielded a positively skewed distribution with the mode at the minimum score. To resolve this, scores were divided into tertiles, and group differences were analyzed by multinomial logistic regression. Table 9 provides descriptive statistics.

### **3.9.6.1 Demographic confounding variables**

Compared to Asian participants, White participants were significantly more likely to be high consumers of alcohol than to be moderate consumers,  $OR = 4.25, p = .02, 95\% CI [1.31, 13.84]$ , or low consumers,  $OR = 9.25, p < .001, 95\% CI [2.78, 30.82]$ . Age did not significantly predict the likelihood of being a low, moderate, or high consumer,  $p > .08$  for each comparison.

### **3.9.6.2 Group differences**

When ethnicity was controlled, runners reported consuming more alcohol than sedentary individuals and yogis. Compared to sedentary individuals, runners were more likely to be in the

top drinking tertile relative to the middle tertile,  $OR = 3.84$ ,  $p = .02$ , 95% CI [1.28, 11.51], and relative to the bottom tertile,  $OR = 16.13$ ,  $p < .001$ , 95% CI [3.74, 69.49]. They were also more likely to be in the middle tertile relative to the bottom tertile,  $OR = 4.2$ ,  $p = .03$ , 95% CI [1.18, 14.97]. Compared to runners, yogis were less likely to be in the high tertile relative to the bottom tertile,  $OR = 0.12$ ,  $p = .001$ , 95% CI [0.03, 0.41], and less likely to be in the middle tertile relative to the bottom tertile,  $OR = 0.21$ ,  $p = .02$ , 95% CI [0.06, 0.75]. Please see Table 9 for descriptive statistics.

### **3.10 Cardiovascular stress reactivity**

Participants were each exposed to two counter-balanced stressors, an arithmetic task ( $M$  correct = 60%) as a cognitive stressor, and a handgrip strength task as a physical stressor. Table 10 provides descriptive statistics for BP and HR change in response to each task and averaged across tasks, by group and in the total sample. Paired t-tests showed that both stressors elicited significant elevations in SBP, DBP, and HR, confirming that the tasks did indeed induce a physiological stress response. For the handgrip task, mean task SBP differed from baseline by a mean of 8.37 ( $SD = 8.00$ ),  $t(137) = -12.29$ ,  $p < .001$ , mean task DBP differed from baseline by a mean of 6.81 ( $SD = 6.12$ ),  $t(137) = -13.08$ ,  $p < .001$ , and mean task HR differed from baseline by a mean of 2.75 ( $SD = 4.43$ ),  $t(137) = -7.28$ ,  $p < .001$ . For the arithmetic task, mean task SBP differed from baseline by a mean of 7.66 ( $SD = 6.71$ ),  $t(135) = -13.31$ ,  $p < .001$ , mean task DBP differed from baseline by a mean of 6.44 ( $SD = 5.11$ ),  $t(135) = 14.7$ ,  $p < .001$ , and mean task HR differed from baseline by a mean of 6.95 ( $SD = 5.42$ ),  $t(135) = -14.96$ ,  $p < .001$ .

Paired-samples t-tests were run to assess whether the arithmetic task and the handgrip task differed in elicited changes in BP and HR. While there were no significant differences on

change in SBP,  $t(131) = .44, p = .66$  or on change in DBP,  $t(131) = -.28, p = .78$ , there was a significant difference in HR change,  $t(131) = -8.52, p < .001$ , whereby the mean HR change for the arithmetic task was greater than the mean HR change for the handgrip task.

In the following analyses, each task was considered individually to be able to compare the effects of each task, addressing different hypotheses by stressor type (somatic versus cognitive), but cardiovascular reactivity was also averaged across both tasks, because averaging across tasks strengthens generalizability to natural stress responses outside the laboratory (Kamarck, Debski, & Manuck, 2000). Reactivity scores (defined as the average of three task readings minus the average of two baseline readings) were considered separately for each cardiovascular measure (SBP, DBP and HR), and respective baseline values were covaried when they significantly predicted reactivity.

### **3.10.1 SBP change in response to the arithmetic task**

Baseline SBP for the arithmetic task did not predict SBP reactivity in response to the arithmetic task,  $\beta < .01, t(134) = -.03, p = .98, R^2 < .01, F(1,134) < .01, p = .98$ .

#### **3.10.1.1 Demographic confounding variables**

For the arithmetic task, race/ethnicity was not related to SBP reactivity,  $F(1,124) = .15, p = .7$ , nor was age,  $\beta = .1, t(134) = 1.12, p = .27, R^2 = .01, F(1,134) = 1.25, p = .27$ .

#### **3.10.1.2 Group and gender differences**

There was no significant gender difference on SBP change in response to the arithmetic task,  $F(1,130) = .24, p = .62$ , and no group by gender interaction,  $F(2,130) = 1.96, p = .15$ . There was no significant group difference on SBP reactivity,  $F(2,130) = 2.44, p = .09$ .

### **3.10.2 SBP change in response to the handgrip task**

Baseline SBP for the handgrip task did not predict SBP reactivity in response to the handgrip task,  $\beta = .09$ ,  $t(136) = 1.01$ ,  $p = .31$ ,  $R^2 = .01$ ,  $F(1,136) = 1.02$ ,  $p = .31$ .

#### **3.10.2.1 Demographic confounding variables**

For the handgrip task, race/ethnicity was not related to SBP reactivity,  $F(1,126) = 3.37$ ,  $p = .07$ , nor was age,  $r(136) = .07$ ,  $p = .43$ .

#### **3.10.2.2 Group and gender differences**

There was a significant gender difference on SBP reactivity for the handgrip task,  $F(1,132) = 15.9$ ,  $p < .001$ , whereby males ( $M = 11.16$ ,  $SD = 7.67$ ) exhibited significantly greater reactivity in SBP compared to females ( $M = 6.09$ ,  $SD = 7.58$ ). There was a marginally significant group difference on SBP reactivity for the handgrip task,  $F(2,132) = 3.01$ ,  $p = .05$ , but post-hoc tests (Scheffé) did not show any significant group differences less than  $p = .1$ . There was no interaction between gender and group on SBP change,  $F(2,132) = 2.49$ ,  $p = .09$ .

### **3.10.3 SBP change averaged across tasks**

Average baseline SBP predicted SBP reactivity averaged across stressors,  $\beta = .21$ ,  $t(141) = 2.5$ ,  $p = .01$ ,  $R^2 = .04$ ,  $F(1,141) = 6.19$ ,  $p = .01$ , and was therefore included as a covariate in subsequent analyses.

#### **3.10.3.1 Demographic confounding variables**

Race/ethnicity was not significantly related to average SBP reactivity,  $F(1,130) = 1.12$ ,  $p = .29$ . Age did not significantly predict average SBP change above average baseline SBP,  $\beta = .05$ ,  $t(140) = .6$ ,  $p = .55$ ,  $R^2 \text{ change} < .01$ ,  $F(1,140) = .36$ ,  $p = .55$ .

### 3.10.3.2 Group and gender differences

After entering average baseline SBP as a covariate, gender was significantly related to average SBP change,  $F(1,136) = 6.66, p = .01$ . Group membership was significantly related to SBP change,  $F(2,136) = 5.68, p < .01$ . A significant group by gender interaction was found,  $F(2,136) = 3.96, p = .02$ . Figure 3 displays this interaction. The corrected alpha was .03. Examining only male participants, simple contrasts reveal that male yogis ( $M = 7.09, SD = 4.06$ ) reacted to stressors with similar SBP reactivity as sedentary males ( $M = 8.9, SD = 4.4$ ),  $p = .23$ , but were significantly less reactive on SBP compared to male runners ( $M = 11.58, SD = 6.15$ ),  $p < .01$ . Male runners reacted to stressors with greater SBP change than sedentary males,  $p = .04$ , but this was not significant at the .03 level. On the other hand, female yoginis ( $M = 8.57, SD = 6.6$ ) reacted to stressors with similar SBP change as female runners ( $M = 7.88, SD = 3.96$ ),  $p = .95$ , but were significantly more reactive than sedentary females on SBP ( $M = 4.43, SD = 3.98$ ),  $p = .02$ . Female runners reacted to stressors with significantly greater SBP change than sedentary females,  $p = .01$ . In summary, female yoginis reacted to stressors in SBP changes similar to female runners, but male yogis reacted similarly to sedentary males.

### 3.10.4 DBP change in response to the arithmetic task

Baseline DBP did not predict DBP change in response to the arithmetic task,  $\beta = -.07$ ,  $t(134) = -.77, p = .45, R^2 < .01, F(1,134) = .59, p = .45$ .

#### 3.10.4.1 Demographic confounding variables

For the arithmetic task, race/ethnicity was not related to DBP reactivity,  $F(1,124) = .35, p = .56$ , nor was age,  $r(134) = .08, p = .37$ .



#### **3.10.4.2 Group and gender differences**

There was no significant gender difference on DBP reactivity for the arithmetic task,  $F(1,130) = .03, p = .86$ , and no significant group difference on DBP reactivity for the arithmetic task,  $F(2,130) = .15, p = .86$ . There was also no interaction between gender and group on DBP change,  $F(2,130) = .86, p = .43$ .

#### **3.10.5 DBP change in response to the handgrip task**

Baseline DBP predicted DBP change in response to the handgrip task,  $\beta = -.19, t(136) = -2.21, p = .03, R^2 = .04, F(1,136) = 4.9, p = .03$ , and was therefore entered as a covariate in subsequent analyses.

##### **3.10.5.1 Demographic confounding variables**

Race/ethnicity was not related to DBP change in the handgrip task,  $F(1,125) = 1.53, p = .22$ . The relationship between age and DBP change in the handgrip task was assessed through hierarchical linear regression analysis with baseline DBP entered in the first step. Age did not contribute additional variance above baseline DBP,  $R^2$  change  $< .001, F(1,135) = .02, p = .88$ .

##### **3.10.5.2 Group and gender differences**

Gender was significantly related to DBP reactivity,  $F(1,131) = 11.03, p < .01$ , whereby males ( $M = 7.98, SD = 5.4$ ) exhibited greater change than females ( $M = 5.85, SD = 6.52$ ). With baseline DBP entered as a covariate, there was a significant group difference on the DBP change in the handgrip task,  $F(2,131) = 5.47, p = .01$ . With a corrected alpha of .03, simple contrasts revealed that runners had a greater DBP reactivity compared to sedentary individuals,  $p = .01$ , but not significantly different from yogis ( $M = 6.51, SD = 6.04$ ),  $p = .05$ . Yogis and sedentary

individuals did not differ on DBP change,  $p = .21$ . There was no significant group by gender interaction,  $F(2,131) = .55, p = .58$ .

### **3.10.6 DBP change averaged across tasks**

Average baseline DBP did not predict DBP reactivity averaged across stressors,  $\beta = -.09$ ,  $t(141) = -1.08, p = .28, R^2 = .01, F(1,141) = 1.16, p = .28$ .

#### **3.10.6.1 Demographic confounding variables**

Race/ethnicity was not significantly related to average DBP change,  $F(1,120) = .17, p = .69$ . Age was not significantly correlated with average DBP change,  $\beta = .01, t(141) = .11, p = .91, R^2 < .001, F(1,141) = .01, p = .91$ .

#### **3.10.6.2 Group and gender differences**

There was no gender difference on average DBP change,  $F(1,137) = 2.57, p = .11$ , and no gender by group interaction,  $F(2,137) = 1.04, p = .36$ . There was a significant group difference in average DBP change,  $F(2,137) = 3.17, p < .05$ . Post-hoc analyses (Scheffé) revealed that runners showed significantly greater DBP reactivity than sedentary individuals,  $p = .04$ , but did not differ from yogis,  $p = .39$  (See Table 10 for descriptive statistics). Yogis and sedentary individuals did not differ,  $p = .52$ .

### **3.10.7 HR change in response to the arithmetic task**

Baseline HR predicted HR change in response to the arithmetic task,  $\beta = -.17, t(134) = -2.01, p < .05, R^2 = .03, F(1,134) = 4.05, p < .05$ , and was included as a covariate in subsequent analyses.

### **3.10.7.1 Demographic confounding variables**

After covarying baseline HR values, race/ethnicity was not related to HR change in the arithmetic task,  $F(1,123) = .14, p = .71$ . The relationship between age and HR change in the arithmetic task was assessed through linear regression analysis with baseline HR entered in the first step. Age did not contribute additional variance above baseline HR,  $\beta = -.04, t = -.41, p = .68$ .

### **3.10.7.2 Group and gender differences**

With baseline HR controlled for, there was no relationship between gender and HR change,  $F(1,129) = .51, p = .48$ , and no significant group difference on HR change in response to the arithmetic task,  $F(2,129) = .53, p = .59$ . There was no group by gender membership interaction,  $F(2,129) = 1.24, p = .29$ .

### **3.10.8 HR change in response to the handgrip task**

Baseline HR for the handgrip task significantly predicted changes in HR,  $\beta = -.28, t(135) = -3.34, p < .001, R^2 = .08, F(1,136) = 11.13, p < .001$ , and were therefore included as a covariate in subsequent analyses.

#### **3.10.8.1 Demographic confounding variables**

After covarying baseline HR values, there was not a significant relationship between race/ethnicity and HR change for the handgrip task,  $F(1,125) = 2.89, p = .09$ . The relationship between age and HR change in the handgrip task was assessed through linear regression analysis with baseline HR entered in the first step. Age did not contribute to additional variance above baseline HR,  $\beta = -.06, t(134) = .66, p = .51, < .01, R^2 \text{ change} < .01, F(1,135) = .44, p = .51$ .

### **3.10.8.2 Group and gender differences**

There was no relationship between gender and HR change,  $F(1,131) = .44, p = .51$ , and no significant group difference on HR change in response to the handgrip task,  $F(2,131) = 2.63, p = .08$ . There was no group by gender membership interaction,  $F(2,131) = 1.94, p = .15$ .

### **3.10.9 HR change averaged across tasks**

Average baseline HR predicted HR reactivity averaged across stressors,  $\beta = -.31, t(141) = -2.78, p = .01, R^2 = .05, F(1,141) = 7.73, p = .01$ , and was therefore included in subsequent analyses.

#### **3.10.9.1 Demographic confounding variables**

With average baseline HR as a covariate, race/ethnicity was not related to average HR change,  $F(1,130) = .59, p = .45$ . Age did not significantly predict average HR change above baseline HR,  $\beta = -.04, t(139) = .47, p = .64, R^2 \text{ change} < .01, F(1,140) = .22, p = .64$ .

#### **3.10.9.2 Group and gender differences**

With average baseline HR as a covariate, there was no gender difference in average HR change,  $F(1,136) < .01, p = .97$ , no group difference in average HR change,  $F(2,136) = 2.66, p = .07$ , and no group by gender interaction,  $F(2,136) = 2.04, p = .13$ .

### **3.10.10 Aerobic fitness and cardiovascular reactivity**

Due to inconsistency in the literature regarding aerobic fitness and cardiovascular stress reactivity and recovery, fitness zone was examined via linear regression, but it did not significantly predict any measure of cardiovascular reactivity or recovery,  $p > .05$  in all cases.

### **3.10.11 Summary of findings on cardiovascular reactivity**

There were several significant group differences in cardiovascular reactivity including: 1) greater SBP change averaged across both tasks in female *yoginis*, the Sanskrit word for female yoga practitioners, compared to sedentary females, 2) greater SBP change averaged across both tasks in female runners compared to sedentary females, 3) lower SBP change averaged across both tasks in male yogis compared to male runners, 4) greater average DBP change across stressors in runners compared to sedentary individuals, and 5) greater DBP change in response to the handgrip task in runners compared to sedentary individuals.

### **3.11 Cardiovascular stress recovery**

Recovery values for SBP, DBP and HR were computed as the average of post-task readings minus the average of baseline readings. Because full BP recovery occurred quickly in this study, the average of only the first two readings was included in the recovery analyses. The mean SBP and DBP values were significantly different from baseline at minutes one and two, but were not significantly different from baseline by minute three,  $t(140) = -1.46, p = .15$ , and  $t(140) = -1.26, p = .21$ , respectively. HR, however, remained significantly different from baseline even at minute five,  $t(137) = -7.28, p < .001$ .

Cardiovascular recovery is considered separately for each task, in order to test specificity hypotheses, and is also averaged in order to increase generalizability from laboratory to life stress responses (Kamarck et al., 2000). Because SBP recovery values were significantly correlated with DBP recovery values in response to the arithmetic task,  $r(139) = .35, p < .001$ , and the handgrip task,  $r(141) = .42, p < .001$ , BP recovery values were considered together in subsequent

MANOVAs. HR was considered separately. Table 12 provides descriptive statistics on differences in BP and HR between baseline and the two-minute recovery period.

### **3.11.1 BP recovery in response to the arithmetic task**

#### **3.11.1.1 Demographic confounding variables**

There was no significant relationship between race/ethnicity and BP recovery, Wilks'  $\Lambda = .99$ ,  $F(2,178) = .83$ ,  $p = .44$ . Age did not predict SBP recovery,  $\beta = .14$ ,  $t(138) = 1.66$ ,  $p = .1$ ,  $R^2 = .02$ ,  $F(1,138) = 2.77$ ,  $p = .1$ , nor did it predict DBP recovery,  $\beta = .07$ ,  $t(138) = .86$ ,  $p = .39$ ,  $R^2 = .01$ ,  $F(1,138) = .73$ ,  $p = .39$ .

#### **3.11.1.2 Group and gender differences**

There was no significant gender difference in BP recovery, Wilks'  $\Lambda = .99$ ,  $F(2,133) = .62$ ,  $p = .54$ , and no significant group difference, Wilks'  $\Lambda = .95$ ,  $F(4, 266) = 1.6$ ,  $p = .17$ . However, there was a significant group by gender interaction, Wilks'  $\Lambda = .9$ ,  $F(4, 266) = 3.65$ ,  $p = .01$  (see Figure 5). This was true for both SBP and DBP. To explain the group by gender interaction, post-hoc tests (Scheffé) were examined for each gender. The only significant difference was poorer SBP recovery in female yoginis compared to female sedentary individuals,  $p = .04$ . No other comparisons approached significance ( $p > .1$ ). Another way of understanding this group by gender interaction is through independent t-tests between males and females of each group. For the yoga group, males had significantly better SBP recovery compared to females,  $t(44) = -2.42$ ,  $p = .02$ . There were no other gender differences for any groups whether on SBP recovery or DBP recovery in response to the arithmetic task,  $p > .1$ .

### **3.11.2 BP recovery in response to the handgrip task**

#### **3.11.2.1 Demographic confounding variables**

Race/ethnicity was marginally significantly related to BP recovery after the handgrip task, Wilks'  $\Lambda = .96$ ,  $F(2,129) = 2.99$ ,  $p = .05$  and was included in subsequent analyses. Asian participants ( $M = -1.35$ ,  $SD = 4.46$ ) had significantly greater recovery in response to the handgrip task compared to White participants ( $M = 1.00$ ,  $SD = 6.09$ ),  $p = .03$ , but there was no race/ethnicity difference on DBP,  $p > .99$ . Age did not significantly predict SBP recovery,  $\beta = -.04$ ,  $t(140) = -.44$ ,  $p = .66$ ,  $R^2 < .01$ ,  $F(1,140) = .19$ ,  $p = .66$ , or DBP recovery,  $\beta = .02$ ,  $t(140) = .2$ ,  $p = .84$ ,  $R^2 < .001$ ,  $F(1,140) = .04$ ,  $p = .84$ .

#### **3.11.2.2 Group and gender differences**

With race/ethnicity controlled, there was no significant gender difference in BP recovery in response to the handgrip task, Wilks'  $\Lambda = .98$ ,  $F(2,119) = 1.14$ ,  $p = .33$ , and no group difference in BP recovery, Wilks'  $\Lambda > .99$ ,  $F(4, 238) = .1$ ,  $p = .98$ . There was no significant interaction between group and gender, Wilks'  $\Lambda = .98$ ,  $F(4, 238) = .63$ ,  $p = .64$ .

### **3.11.3 BP recovery averaged across tasks**

#### **3.11.3.1 Demographic confounding variables**

Race/ethnicity was not related to BP recovery, Wilks'  $\Lambda = .98$ ,  $F(2,127) = 1.61$ ,  $p = .21$ . Age did not significantly predict SBP recovery,  $\beta = .06$ ,  $t(138) = .67$ ,  $p = .51$ ,  $R^2 < .01$ ,  $F(1,138) = .45$ ,  $p = .51$ , nor did it predict DBP recovery,  $\beta = .02$ ,  $t(138) = .21$ ,  $p = .83$ ,  $R^2 < .001$ ,  $F(1,138) = .05$ ,  $p = .83$ .

### 3.11.3.2 Group and gender differences

There was no significant gender difference in BP recovery averaged across tasks, Wilks'  $\Lambda = .97$ ,  $F(2,133) = .27$ ,  $p = .76$ , and no significant group difference, Wilks'  $\Lambda = .97$ ,  $F(4, 266) = 1.1$ ,  $p = .36$ . There was, however, a significant group by gender interaction, Wilks'  $\Lambda = .92$ ,  $F(4, 266) = 2.77$ ,  $p = .03$  (see Figure 4), revealing the same pattern as for the arithmetic task alone. Examining the individual ANOVAs, this interaction held for SBP,  $F(2,134) = 4.57$ ,  $p = .01$ , but not for DBP,  $F(2,134) = 2.74$ ,  $p = .07$ . To understand this interaction, Post-hoc analyses (Scheffé) were examined separately for each gender. The only significant group difference was a significantly poorer SBP recovery in female yoginis compared to sedentary individuals,  $p = .01$  (see Table 12 for descriptive statistics by group and gender). Female yoginis did not differ from female runners in SBP recovery,  $p = .09$ . The female runners and sedentary females did not differ,  $p = .73$ . When examining only males, male yogis did not differ in SBP recovery from sedentary males,  $p = .83$  or from male runners,  $p = .21$ . Male runners did not differ in SBP recovery from sedentary males,  $p = .46$ .

Another way of understanding this group by gender interaction is through independent t-tests between males and females of each group. For the yoga group, males had significantly better SBP recovery compared to females,  $t(44) = -2.12$ ,  $p = .04$ . For the running group, females had marginally significantly better SBP recovery compared to males,  $t(42) = 1.99$ ,  $p = .05$ . For the sedentary group, males and females did not differ in SBP recovery,  $t(48) = 1.21$ ,  $p = .23$ .



### **3.11.4 HR recovery in response to the arithmetic task**

#### **3.11.4.1 Demographic confounding variables**

There was no significant relationship between race/ethnicity and HR recovery,  $F(1,129) = .03, p = .87$ . Age did not significantly predict HR recovery,  $\beta = -.02, t(139) = -.18, p = .86, R^2 < .001, F(1, 139) = .03, p = .86$ .

#### **3.11.4.2 Group and gender differences**

There was no significant gender difference in HR recovery,  $F(1, 135) = .56, p = .46$ , no significant group difference in HR recovery,  $F(2, 138) = 1.53, p = .22$ , and no group by gender interaction,  $F(2, 135) = 0.07, p = .93$ .

### **3.11.5 HR recovery in response to the handgrip task**

#### **3.11.5.1 Demographic confounding variables**

There was no relationship between race/ethnicity and HR recovery,  $F(1, 131) = .17, p = .68$ , and age did not predict HR recovery,  $\beta = .001, t(140) = .01, p = .99, R^2 < .001, F(1, 140) < .001, p = .99$ .

#### **3.11.5.2 Group and gender differences**

There was no gender difference in HR recovery,  $F(1, 137) = .05, p = .82$ , nor was there a significant group difference in HR recovery,  $F(2, 137) = .8, p = .45$ . There was no group by gender interaction,  $F(2, 137) = .16, p = .86$ .

### **3.11.6 HR recovery averaged across tasks**

#### **3.11.6.1 Demographic confounding variables**

Race/ethnicity was not related to HR recovery averaging across both tasks,  $F(1, 129) < .01, p = .95$ , nor was age,  $\beta = -.01, t(138) = -.07, p = .95, R^2 < .001, F(1, 139) < .01, p = .95$ .

#### **3.11.6.2 Group and gender differences**

There was no gender difference in HR recovery,  $F(1,135) = .13, p = .72$ , no group difference,  $F(2,135) = .32, p = .73$ , and no group by gender interaction,  $F(2,135) = .43, p = .66$ .

### **3.11.7 Summary of results on cardiovascular stress recovery**

There were only two instances of significant differences between groups: 1) Poorer recovery in SBP recovery across tasks in female yoginis compared to sedentary females, and 2) poorer recovery in SBP recovery in response to the arithmetic task in female yoginis compared to sedentary females.

## **3.12 State anxiety (STICSA-S)**

Table 11 provides descriptive statistics for state anxiety change by task and by type, in each group and in the total sample. To assess whether there was an order effect of stressor presentation, paired-samples t-tests were run to determine if change in somatic state anxiety or cognitive state anxiety differed significantly between the first and second task presented. There was no order effect of stressor presentation for change for somatic state anxiety or cognitive state anxiety, demonstrated by the lack of significant differences between the first and second task, for total state anxiety,  $t(136) = -1.13, p = .26$ , for somatic state anxiety,  $t(137) = -.91, p = .37$ , and for cognitive state anxiety,  $t(139) = -.91, p = .36$ . To assess whether the stressors differed in total

state anxiety change, a paired-sample t-test was run and revealed no significant difference,  $t(136) = 1.03, p = .31$ .

### **3.12.1 Manipulation check**

The STICSA-S was used as a manipulation check. I predicted that the isometric handgrip task would induce a greater increase in somatic anxiety than the arithmetic task, and that the mental arithmetic task would induce a greater increase in cognitive anxiety than the handgrip task. As predicted, the handgrip task induced a greater change in somatic anxiety than the arithmetic task,  $t(137) = -2.92, p < .01$ , while the arithmetic task induced a greater change in cognitive anxiety compared to the handgrip task,  $t(139) = 5.36, p < .001$ . However, somatic anxiety change was greater than cognitive anxiety change, both for the arithmetic task,  $t(140) = -3.57, p < .001$ , and for the handgrip task,  $t(138) = 11.65, p < .001$ .

### **3.12.2 Relationship between trait anxiety and state anxiety**

Inconsistent with findings by Ree et al. (2008), trait anxiety type (i.e., somatic and cognitive) was not associated with anxiety increases by task. Higher levels of trait cognitive anxiety did not predict greater increases in total state anxiety in response to the cognitive arithmetic task,  $\beta = .14, t(134) = 1.58, p = .12, R^2 = .02, F(1, 134) = 2.48, p = .12$ . Trait somatic anxiety also did not predict total state anxiety change in response to the somatic handgrip task,  $\beta = -.05, t(130) = -.57, p = .57, R^2 < .01, F(1, 130) = .33, p = .57$ .

The STICSA-T anxiety types also did not predict the type of anxiety experienced under stress. Trait somatic anxiety did not predict state somatic anxiety change averaged across the tasks,  $\beta = -.03, t(130) = -.34, p = .74, R^2 < .01, F(1, 13) = .11, p = .74$ , and trait cognitive anxiety

did not predict state cognitive change averaged across the tasks,  $\beta = -.08$ ,  $t(127) = -.92$ ,  $p = .36$ ,  $R^2 = .01$ ,  $F(1, 127) = .84$ ,  $p = .36$ .

### **3.12.3 Specific anxiety predictions**

#### **3.12.3.1 Somatic and cognitive trait anxiety**

##### **3.12.3.1.1 Demographic confounding variables**

Race/ethnicity was not related to trait somatic anxiety,  $F(1, 130) = .03$ ,  $p = .87$ , nor to trait cognitive anxiety,  $F(1, 132) = 1.2$ ,  $p = .28$ . Age was neither related to trait somatic anxiety,  $\beta = .04$ ,  $t(140) = .52$ ,  $p = .6$ ,  $R^2 = .04$ ,  $F(1, 140) = .27$ ,  $p = .6$  nor to trait cognitive anxiety,  $\beta = -.06$ ,  $t(142) = -.71$ ,  $p = .48$ ,  $R^2 = .06$ ,  $F(1, 142) = .5$ ,  $p = .48$ .

##### **3.12.3.1.2 Group and gender differences**

There was no gender difference on trait somatic anxiety,  $t(1, 136) = .29$ ,  $p = .59$ , or on trait cognitive anxiety,  $t(1, 138) = .12$ ,  $p = .73$ . There were significant group differences on trait somatic anxiety,  $t(2, 136) = 8.53$ ,  $p < .001$ , and on trait cognitive anxiety,  $t(2, 138) = 10.59$ ,  $p < .001$ . Post-hoc analysis (Scheffé) revealed that yogis scored significantly lower on trait somatic anxiety,  $p = .01$ , and trait cognitive anxiety,  $p = .001$ , compared to sedentary individuals. Runners scored significantly lower on trait somatic anxiety,  $p = .001$ , and trait cognitive anxiety,  $p < .001$  compared to sedentary individuals. Yogis and runners did not differ from each other on trait somatic anxiety,  $p = .8$  or on trait cognitive anxiety,  $p = .99$ . There were no significant interactions between group and gender on trait somatic anxiety,  $t(2, 136) = .54$ ,  $p = .59$ , or on trait cognitive anxiety,  $t(2, 138) = .09$ ,  $p = .91$ .

### **3.12.3.2 State anxiety change in response to the arithmetic task**

#### **3.12.3.2.1 Demographic confounding variables**

Race/ethnicity was not related to state anxiety change in response to the arithmetic task,  $F(1, 125) = .01, p = .93$ , nor was age,  $\beta = -.01, t(135) = -.09, p = .93, R^2 < .01, F(1, 135) = .01, p = .93$ .

#### **3.12.3.2.2 Group and gender differences**

There was no gender difference in state anxiety change in response to the arithmetic task,  $t(1, 131) = .02, p = .89$ , nor was there a significant interaction between group and gender on state anxiety change,  $t(2, 131) = .05, p = .95$ . There was no group difference on total state anxiety change in the arithmetic task,  $F(2, 131) = 1.34, p = .27$ .

### **3.12.3.3 State anxiety change in response to the handgrip task**

#### **3.12.3.3.1 Demographic confounding variables**

Race/ethnicity was not related to total state anxiety change in response to the handgrip task,  $F(1, 122) = .33, p = .57$ , nor was age,  $\beta = -.03, t(132) = -.3, p = .76, R^2 < .01, F(1, 132) < .09, p = .76$ .

#### **3.12.3.3.2 Group and gender differences**

There was a significant gender difference in total state anxiety change in response to the handgrip task,  $F(1, 128) = 10.9, p = .001$ , whereby males ( $M = 3.31, SD = 3.86$ ) had a greater increase than females ( $M = 1.56, SD = 3.34$ ). There was no significant group difference on state

anxiety change in response to the handgrip task,  $F(2, 128) = 1.93, p = .15$ , and no significant group by gender interaction,  $F(2, 128) = .44, p = .64$ .

### **3.12.3.4 State cognitive anxiety change averaged across both tasks**

#### **3.12.3.4.1 Demographic confounding variables**

There was no relationship between race/ethnicity and state cognitive anxiety change,  $F(1, 119) = .03, p = .86$ , and age did not predict state cognitive anxiety change,  $\beta = -.08, t(128) = -.94, p = .35, R^2 = .01, F(1, 128) = .88, p = .35$ .

#### **3.12.3.4.2 Group and gender differences**

There was no significant gender difference in state cognitive anxiety change,  $F(1, 124) = .71, p = .4$ , no significant group difference,  $F(2, 124) = 2.43, p = .09$ , and no group by gender interaction,  $F(2, 124) = .71, p = .4$ .

### **3.12.3.5 State somatic anxiety change averaged across both tasks**

#### **3.12.3.5.1 Demographic confounding variables**

There was no relationship between race/ethnicity and state somatic anxiety change,  $F(1, 124) = .08, p = .78$ , and age did not predict state somatic anxiety change,  $\beta = .71, t(133) = -.76, p = .45, R^2 < .01, F(1, 133) = .58, p = .45$ .

### **3.12.3.5.2 Group and gender differences**

There was a significant gender difference in state somatic anxiety change,  $F(1, 129) = 7.47, p = .01$ , whereby males ( $M = 2.57, SD = 2.01$ ) reported significantly greater somatic anxiety change compared to females ( $M = 1.68, SD = 1.72$ ). There was no significant group difference in state somatic anxiety change,  $F(2, 129) = 1.16, p = .32$ , and no group by gender interaction,  $F(2, 129) = 1.55, p = .22$ .

### **3.13 Mediation**

This section attempts to explain differences in outcome measures found between yoga participants and sedentary individuals. There were two outcome measures that differed significantly between yoga participants and sedentary participants: 1) resting HR and 2) lnHF. In order to understand these group differences, proposed potential mediators (see Figure 1) were tested when they were found to be different between yogis and sedentary individuals. These variables included depression, trait anxiety, hostility, respiration rate, aerobic fitness, whether an individual was vegetarian, and whether an individual was a cigarette smoker. As is described in section 3.13.1 and 3.13.2, the relationship between yoga membership and lower HR was partially mediated by aerobic fitness, and no other variable, while the relationship between yoga membership and higher HF power was partially mediated by respiration rate and aerobic fitness, and no other variable.

#### **3.13.1 Mediation of the relationship between yoga membership and lower HR**

Group membership was dummy-coded into 1 (Yoga) and 0 (Non-yoga). Analyses proceeded in four stages. In the first stage, I confirmed that belonging to the yoga group versus

sedentary group predicted resting HR in a regression,  $\beta = -.32$ ,  $t(96) = -3.29$ ,  $p = .001$ ,  $R^2 = .1$ ,  $F(1,96) = 10.79$ ,  $p = .001$ .

The second stage of mediation analysis according to Baron and Kenny is to verify that belonging to the yoga group versus sedentary group significantly predicted the potential mediators which was previously accomplished through ANOVA or MANOVA. These included depression, trait anxiety, hostility, cigarette smoking, vegetarianism, aerobic fitness, and respiration.

In the third testing stage, I tested whether the potential mediators predicted HR. Only aerobic fitness zone significantly predicted HR,  $\beta = .38$ ,  $t(92) = 4.96$ ,  $p < .001$ ,  $R^2 = .13$ ,  $F(1,92) = 15.64$ ,  $p < .001$ . The other variables did not significantly predict HR, including depression,  $\beta = .04$ ,  $t(95) = .36$ ,  $p = .72$ ,  $R^2 < .001$ ,  $F(1,95) = .13$ ,  $p = .72$ , trait anxiety,  $\beta = -.03$ ,  $t(92) = -.31$ ,  $p = .75$ ,  $R^2 < .01$ ,  $F(1,91) < .1$ ,  $p = .75$ , hostility,  $\beta = -.18$ ,  $t(95) = -1.79$ ,  $p = .08$ ,  $R^2 = .03$ ,  $F(1,95) = 3.21$ ,  $p = .08$ , cigarette smoking,  $\beta = -.08$ ,  $t(95) = -.74$ ,  $p = .46$ ,  $R^2 = .01$ ,  $F(1,95) = .55$ ,  $p = .46$ , vegetarianism,  $\beta = -.04$ ,  $t(95) = -.41$ ,  $p = .68$ ,  $R^2 < .01$ ,  $F(1,95) = .17$ ,  $p = .68$ , and respiration rate,  $\beta = -.08$ ,  $t(94) = -.77$ ,  $p = .44$ ,  $R^2 = .01$ ,  $F(1,94) = .59$ ,  $p = .44$ .

In the fourth testing stage, aerobic fitness zone emerged as a mediator via hierarchical linear regression, where it was entered in the first step, and group membership in the last step. Aerobic fitness zone remained significant,  $\beta = .38$ ,  $t(92) = 3.96$ ,  $p < .001$ ,  $R^2 = .2$ ,  $F(1,93) = 21.65$ ,  $p < .001$ , and the indirect effect was confirmed to be significant by the Sobel test,  $Z = -2.32$ ,  $p = .02$ . Group membership only marginally significantly predicted HR,  $\beta = -.19$ ,  $t(92) = -1.98$ ,  $p = .05$ ,  $R^2$  change = .03,  $F(1,92) = 3.93$ ,  $p = .05$ , indicating partial mediation of the relationship between yoga and resting HR by aerobic fitness zone.



### 3.13.2 Mediation of the relationship between yoga membership and higher lnHF

In the first stage, I confirmed that, after entering ethnicity and age, belonging to the yoga group versus sedentary group predicted HR in a regression above and beyond ethnicity and age,  $\beta = -.38$ ,  $t(84) = 3.86$ ,  $p < .001$ ,  $R^2$  change = .13,  $F(1,84) = 14.87$ ,  $p < .001$ . The second stage confirmed that belonging to the yoga group versus sedentary group significantly predicted the relevant variables.

In the third stage, I tested whether the potential mediators predicted HF power, above and beyond ethnicity and age. Respiration rate, aerobic fitness zone, and depression significantly predicted lnHF power,  $\beta = -.35$ ,  $t(84) = -3.58$ ,  $p = .001$ ,  $R^2 = .11$ ,  $F(1,84) = 12.79$ ,  $p = .001$ ;  $\beta = -.37$ ,  $t(81) = -3.88$ ,  $p < .001$ ,  $R^2 = .13$ ,  $F(1,84) = 15.04$ ,  $p < .001$ ; and  $\beta = -.22$ ,  $t(93) = -2.19$ ,  $p = .03$ ,  $R^2 = .05$ ,  $F(1,93) = 4.8$ ,  $p = .03$ , respectively. Trait anxiety did not predict lnHF power,  $\beta = -.08$ ,  $t(79) = .76$ ,  $p = .45$ ,  $R^2 = .01$ ,  $F(1,79) = .58$ ,  $p = .45$ , nor did hostility,  $\beta = -.14$ ,  $t(93) = -1.4$ ,  $p = .17$ ,  $R^2 = .02$ ,  $F(1,93) = 1.96$ ,  $p = .17$ . Cigarette smoking did not significantly predict lnHF power,  $\beta = -.18$ ,  $t(93) = -1.8$ ,  $p = .08$ ,  $R^2 = .03$ ,  $F(1,93) = 3.22$ ,  $p = .08$ , nor did vegetarianism,  $\beta = -.08$ ,  $t(93) = -.73$ ,  $p = .47$ ,  $R^2 = .01$ ,  $F(1,93) = .53$ ,  $p = .47$ .

In the fourth stage, respiration rate, aerobic fitness, and depression were tested as mediators via hierarchical linear regression. Ethnicity and age were entered into the first step, the potential mediator was entered in the second step, and group membership was entered in the last step. When this procedure was completed, depression was no longer significant,  $\beta = -.09$ ,  $t(83) = -.92$ ,  $p = .36$ ,  $R^2 = .04$ ,  $F(1,84) = 3.69$ ,  $p = .06$ , and the Sobel test indicated that indirect effect was not significant,  $Z = .96$ ,  $p = .34$ . Yoga membership remained a significant predictor of lnHF power,  $\beta = .36$ ,  $t(83) = 3.4$ ,  $p = .001$ ,  $R^2$  change = .1,  $F(1,83) = 11.53$ ,  $p = .001$ , indicating that depression did not mediate the relationship between group membership and lnHF. Respiration

rate, however, emerged as a partial mediator of the relationship between yoga membership and higher lnHF. Respiration rate remained a significant predictor,  $\beta = -.26$ ,  $t(83) = -2.69$ ,  $p = .01$ ,  $R^2 = .11$ ,  $F(1,84) = 12.79$ ,  $p = .001$ , and the indirect effect was significant,  $Z = 2.07$ ,  $p = .04$ , while yoga membership also remained a significant predictor of lnHF power,  $\beta = .31$ ,  $t(83) = 3.03$ ,  $p < .01$ ,  $R^2 \text{ change} = .07$ ,  $F(1,83) = 9.17$ ,  $p < .01$ . When aerobic fitness zone was entered in the second step, with yoga membership in the final step, aerobic fitness also emerged as a partial mediator. Aerobic fitness zone remained significant,  $\beta = -.29$ ,  $t(80) = -3.00$ ,  $p < .01$ ,  $R^2 \text{ change} = .13$ ,  $F(1,81) = 15.04$ ,  $p < .001$ , the indirect effect was significant,  $Z = 2.17$ ,  $p = .03$ , and group membership remained significant in predicting lnHF power,  $\beta = .27$ ,  $t(80) = 2.63$ ,  $p = .01$ ,  $R^2 \text{ change} = .06$ ,  $F(1,80) = 6.91$ ,  $p = .01$ .

Finally, respiration rate and aerobic fitness were entered in the second step, and yoga membership was entered into the third step. Aerobic fitness zone and respiration rate accounted for 19% additional variance above ethnicity and age,  $R^2 \text{ change} = .19$ ,  $F(2,80) = 11.55$ ,  $p < .001$ . Yoga membership accounted for 4% additional variance in lnHF power,  $\beta = .22$ ,  $t(79) = 2.11$ ,  $p = .04$ ,  $R^2 \text{ change} = .04$ ,  $F(1,79) = 4.45$ ,  $p = .04$ , above and beyond the partial mediators of respiration rate and aerobic fitness, and after accounting for race/ethnicity and age.

### **3.14 Beliefs about yoga**

To follow up the finding that yoga professionals endorse a wide range of medical problems that can be effectively treated with yoga (Long et al., 2001), participants were asked to indicate whether or not they believed that yoga could prevent, improve, and cure cardiovascular disease and cancer, or whether they believed that yoga had no effect on these diseases. Responses can be seen by group in Table 13. For beliefs about yoga's effect on cardiovascular disease, 50%

of the total sample (60% of yogis) endorsed that yoga could prevent it, 63% of the total sample (68% of yogis) endorsed that yoga could improve it, and 12% of the total sample (29% of yogis) endorsed the belief that yoga could cure cardiovascular disease. For beliefs about yoga's effect on cancer, 26% of the total sample (47% of yogis) endorsed that yoga could prevent it, 33% of the total sample (57% of yogis) endorsed that yoga could improve it, and 8% of the total sample (17% of yogis) endorsed the belief that yoga could cure cancer.

## **4 Discussion**

### **4.1 Summary of findings**

The present cross-sectional study does not allow for conclusions on causal connections between yoga or running on cardiovascular health outcomes. Instead, the study demonstrated that long-term, regularly practicing yogis and runners show similar advantages on numerous psychological and physiological markers of cardiovascular health compared to sedentary individuals. Both yogis and runners, compared to sedentary individuals, showed lower resting HR, lower resting HF power, superior aerobic fitness levels, lower incidence of cigarette smoking, and lower reported depressive symptoms, anxious symptoms, and hostility. There was little specificity between the yogis and runners, with the exception of a greater rate of vegetarianism in the yoga group, lower respiration rate in Ujjayi-breathing yogis and social support, sleep quality, and alcohol consumption in the running group. In this discussion chapter, I provide a detailed summary of specific findings interpreted in the context of the existing research literature, acknowledge study limitations, highlight study contributions, and provide suggestions for future research.

#### **4.1.1 Resting physiological outcome measures**

The prediction that yogis and runners would have lower resting HR, SBP, and DBP and higher HRV compared to sedentary individuals was supported for HR and HRV, but no group differences were found on BP. To understand the null results on BP, it is important to note that the present study's sedentary group had lower BP than expected. The sedentary group (aged 20-59) appears to have similar HR, but lower SBP and DBP ( $M = 105/67$  mmHg) compared to the national average (Bryan, St-Pierre Larose, Campbell, Clarke, & Tremblay, 2010). In a Canadian

nationally representative sample, individuals ages 20-39 had a mean SBP of 104 mmHg and DBP of 68 mmHg at their sixth reading (Bryan et al., 2010). For ages 40-59, mean SBP was 112 mmHg and DBP was 74 mmHg. This discrepancy in BP between the present sample and the national average may also be explained by the exclusion of individuals with known hypertension in the present study. There also could have been a sampling problem in the present study, whereby the sedentary group was more active than they reported or whereby the screening procedure did not adequately address physical activity, such as walking for pleasure or transportation. Additionally, the lower than expected BP in this group may be explained by selection bias due to the participants' prior knowledge that they would be asked to perform an aerobic fitness test in the laboratory.

The lack of consideration of the use of non-steroidal anti-inflammatory drugs (NSAIDS) in this study may have limited the interpretation of the absence of differences in resting blood pressure between groups. NSAIDS have been shown by meta-analysis to increase resting blood pressure in normotensives and in those taking anti-hypertensive medication by a pooled mean blood pressure of 5 mmHG (Johnson, Nguyen, & Day, 1994). There have been group differences in the use of NSAIDS, but this was not assessed in the current study. Athletes have been shown to use NSAIDS frequently in order to improve short-term recovery of muscle function and to reduce soreness associated with exercise (Ciocca, 2005). Runners may therefore be more likely to use NSAIDS compared to sedentary individuals. Although yoga is considered more gentle than running, it is also conceivable that yoga practitioners may also be more likely to use NSAIDS relative to sedentary individuals. It is therefore possible that the use of NSAIDS by runners, and even yoga practitioners, in the present study obscured advantages in resting blood pressure

compared to sedentary individuals, but this cannot be determined without having investigated NSAID use.

A separate question is whether or not it is surprising that the yoga and running groups did not have lower BP compared to the sedentary group. Moreover, the relationship of BP to health is not linear; either very low or elevated BP is problematic. Given the sedentary group's average of 105/67 mmHg, it is unlikely that even lower BP would be considered beneficial. BP may follow the law of diminishing returns in terms of cardiovascular risk reduction, and there is evidence, although restricted to patients with coronary artery disease, that lowering blood pressure past a certain point actually increases the risk of future cardiovascular events excluding stroke, at 110/60 mmHg (Bangalore et al., 2010) and at a DBP of 70 mmHg (Messerli et al., 2006).

Finally, it is also possible that the null results are due to range restriction in BP in our sample. BP differences attributed to different practices may not emerge until later in life, and our cut-off of age 59 may have limited the ability to find group differences. The exclusion of adults above the age of 59 and of adults with known hypertension may have contributed to a floor effect. The lack of group differences on BP in this cross-sectional study in healthy adults does not preclude that yoga or running can have long-term beneficial effects on blood pressure, and indeed past research indicates that they do, with especially strong evidence for running (e.g., Whelton et al., 2002).

While race/ethnicity was not part of the study hypotheses, the present study was the first to demonstrate that Asian adults had lower HF power compared to White adults. It has been previously demonstrated in a Canadian study that Asian children have lower HF power, higher LF, and higher LF/HF power ratio than White children (Reed, Warburton, Whitney, & McKay, 2006). Though racial/ethnic differences in HRV comparing Asian and White adults have not been

previously examined, studies have demonstrated that African Americans have lower HF power, higher LF/HF power ratio, and higher LF compared to White participants (Choi et al., 2006). The racial/ethnic difference found in the present study is beyond the scope of this paper, but understanding the mediators underlying this difference as well as replicating this finding and conducting a more detailed assessment of ethnicity would be fruitful for future study.

#### **4.1.2 Mediation**

The present study was the first to attempt to understand differences in cardiovascular indices between yogis and sedentary individuals. Mediation of the group differences in resting HR and HRV between the yoga and sedentary groups were examined. Aerobic fitness, which was superior in the yoga group compared to the sedentary group (though inferior to the running group, as predicted), was a partial mediator largely explaining the relationship between yoga membership and lower resting HR compared to sedentary individuals, with three percent variance remaining explained by yoga membership. This finding highlights the importance of differentiating between styles of yoga, because it suggests that yoga practitioners may only show lower resting HR to the extent that their yoga practice is vigorous enough to influence aerobic fitness. The present study found no differences in aerobic fitness between yoga participants who were divided by the estimated aerobic intensity of the yoga style they practice. While this suggests that even low intensity yoga practice may be associated with greater aerobic fitness, the categorization of yoga style into two subgroups was based on crude estimation, and more work is needed to understand the aerobic intensity of different yoga styles. Ideally, future studies of yoga intervention would measure aerobic intensity, report the yoga style or styles included, or restrict or compare yoga styles of differing intensities.

The yoga group's higher HRV (measured by HF) compared to the sedentary group was partially mediated by aerobic fitness and respiration rate, with four percent of the variance remaining explained by yoga membership. As with HR, this finding has the same implication that the aerobic intensity associated with yoga styles is an important factor to consider in researching yoga and cardiovascular health. The finding that lower respiration rate partially accounts for higher HF power, however, suggests that yoga may offer something that sets it apart from aerobic exercise.

As predicted, the yoga group exhibited a lower resting respiration rate compared to the sedentary group, while the running group did not differ from the sedentary group. Respiration rate and vegetarianism were the only measures in the present study on which yogis, and not runners, emerged as superior to sedentary individuals in terms of cardiovascular health. This finding contributes to the evidence that yoga is uniquely associated with positive lung function, joining Prakash et al. (2001), who demonstrated that regular male yoga practitioners had greater peak expiratory flow rates compared to male runners and sedentary males. In our sample, the majority (70%) of the yoga practitioners practiced Ujjayi breathing. Although the total yoga group did not significantly differ from the running group, the yoga practitioners who practiced Ujjayi breathing took significantly fewer breaths per minute compared to both runners and sedentary individuals. Future research involving yoga and lung function would, therefore, benefit from attention to breathing techniques.

## **4.2 Cardiovascular reactivity and recovery**

The data did not support the prediction that yogis and runners would show less sympathetic activation (i.e., less reactivity and superior recovery) compared to sedentary



individuals in response to both stressors, nor did it support that the yoga group would exhibit less sympathetic activation compared to the running group in response to the cognitive stressor. The novel research question of whether or not yogis and runners react differentially to somatic relative to cognitive stressors was actually made irrelevant or inappropriate by the fact that yogis and runners actually displayed *greater* sympathetic activation compared to sedentary individuals, when any group differences were found. Findings did not support the notion that yoga or running attenuates the cardiovascular stress response regardless of stressor type, though it is still possible that intervention studies could yield different results than this cross-sectional study.

Results indicated that runners displayed greater DBP reactivity compared to sedentary individuals in response to the handgrip task and averaged across tasks. In females, yoginis and runners also showed greater SBP reactivity, averaged across tasks, compared to sedentary females. Female yoginis also showed poorer SBP recovery compared to sedentary females in response to the arithmetic task, and averaged across both tasks.

The instances of increased cardiovascular reactivity in the yoga and running groups compared to the sedentary group may have resulted from differences in levels of engagement between the groups. Both the arithmetic task and the handgrip task allowed for participants to disengage and withdraw their effort without consequence, and level of engagement was not assessed. The stressors used in the present study may, therefore, have been relatively innocuous to individuals who disengaged. It is possible that the yoga and running groups may have engaged more strongly compared to the sedentary group. Given that runners scored more highly than sedentary individuals on conscientiousness, which has been associated with perseverance and achievement orientation (Digman, 1990), there is a suggestion that this may have accounted for

the runner's greater cardiovascular reactivity relative to sedentary individuals, though this does not explain increased reactivity in yoga practitioners.

These complicated results add to an equally complicated research literature on reactivity and recovery in yoga and exercise groups. There was previous evidence that expert yoginis were less reactive to stressors compared to novice yoginis in terms of HR (Kiecolt-Glaser et al., 2010), and that yogis had lower DBP reactivity compared to controls (Patel, 1975), but also that meditators showed greater HR in anticipation of stressors (Goleman et al., 1976; Lehrer et al., 1980). The present study's findings were somewhat in line with Lehrer et al. (1980) and Goleman et al. (1976); however, the time of measurement in those studies was too different from the present study to reasonably compare results. Kiecolt-Glaser's (2010) findings, which were based on an all-female sample, conflict with the present study's findings that female yogis exhibited greater reactivity compared to sedentary females. It should be noted that the stressors used in Kiecolt-Glaser et al.'s study differed from the present study's in that they combined the cold pressor task, a different somatic stressor, and a different version of a mental arithmetic task involving feedback from the experimenter which renders the task a social stressor, as opposed to a solely cognitive stressor. It appears that the stressors used in Kiecolt-Glaser et al.'s study together raised HR by over 10 beats per minute, while the stressors in the present study produced an increase of less than five. While there is no obvious explanation to reconcile these opposite findings, type of stressor, magnitude of change in HR and BP, and gender are clearly important to consider in future research to resolve conflicting results in the literature.

Meta-analyses of the association between aerobic fitness or exercise groups and cardiovascular reactivity and recovery have been unclear. On one hand, reviewers have concluded that aerobic fitness was associated with less HR and DBP reactivity and superior HR

recovery (Forcier et al., 2006), but on the other hand, other reviewers have found that exercise group membership was not associated with reactivity or recovery, and that aerobic fitness was even associated with greater HR reactivity (Jackson & Dishman, 2006). The present study's findings were not entirely consistent with any of these previous meta-analytic results, given that the running group exhibited greater DBP reactivity compared to sedentary individuals, and that aerobic fitness was unrelated to cardiovascular reactivity and recovery.

A broader issue raised by the present findings is the implication for the concept of cardiovascular reactivity. If greater cardiovascular reactivity is associated with increased risk of hypertension, but physical activity like running is associated with decreased risk of hypertension, how can the present study's findings that runners had greater cardiovascular reactivity be understood in terms of health risk? While it is unclear why the present study as well as others in the literature have found greater reactivity in more active individuals, it is important to note that the reactivity likely contributes to hypertension only to the extent that it represents prolonged sympathetic activation in real life (Schwartz, Gerin, Davidson, Pickering, Brosschot, Thayer, ... Linden, 2003). Because there were no differences in BP recovery accompanying the greater DBP reactivity in runners, the brief and small difference in DBP reactivity is likely not very meaningful. That there was both greater reactivity and poorer recovery in female yoginis compared to sedentary individuals is more theoretically troubling, and, given the relatively few studies of female yoga practitioners and stress reactivity, future studies are needed to examine whether this group difference is replicable.

### **4.3 Trait and state somatic and cognitive anxiety**

Inconsistent with Ree et al.'s (2008) findings, trait anxiety type (i.e., somatic and cognitive) did not differentially predict total state anxiety change in response to respective cognitive and somatic stressors. This question had clinical relevance in the opportunity to use the trait measure to identify the type of stressor that is more likely to provoke state anxiety in individuals. This study did not support the usefulness of this approach; however, methodological differences between the present study and Ree et al.'s study could explain the present study's null findings. The stressors that Ree and colleagues used in their study included a real-life examination stressor and a 15-minute CO<sub>2</sub> inhalation stressor that each induced greater state anxiety change than the stressors in the present study. The interpretation of our null findings is greatly limited by the small magnitude of changes in anxiety.

An additional possibility that was examined in the present study was that trait anxiety type would predict the respective type of state anxiety experienced in response to laboratory stressors, but this was also not the case (e.g., trait somatic anxiety did not predict state somatic anxiety change). The STICSA state scale did, however, appropriately distinguish between the arithmetic task, which elicited more cognitive anxiety, and the handgrip task, which elicited more somatic anxiety, confirming Ree et al.'s (2008) validation findings, and inspiring confidence that the scales did measure cognitive and somatic anxiety as intended.

Contrary to hypotheses, yogis and runners did not differ on trait somatic anxiety and trait cognitive anxiety, though each group reported significantly less somatic and cognitive anxiety compared to the sedentary group. These results are consistent with Benson's (1975) generalized relaxation response, and inconsistent with Schwartz et al.'s (1978) theory that cognitively-focused techniques exert specific cognitive anxiety benefits, while somatically-focused

techniques exert specific somatic anxiety benefits, superimposed on a generalized relaxation response.

Also contrary to hypotheses, there were no group differences in the magnitude of change in state somatic anxiety or state cognitive anxiety in response to stressors. I had predicted that yogis and runners would show less change in state somatic anxiety compared to sedentary individuals, and that only the yogis would report less change in state cognitive anxiety compared to sedentary individuals, in accordance with the specificity hypothesis posited by Schwartz et al. (1978). The absence of any group differences in state anxiety could be explained by the small magnitude of change in somatic anxiety induced by the laboratory stressors. Another limitation in adequately testing the specificity hypothesis is that it may not be appropriate to assume that yoga and running differ in terms of cognitive and somatic focus. I had characterized yoga as both somatically-focused and cognitively-focused when building hypotheses, but it is possible that, in this sample, yoga could have been more purely somatically-focused, like running. To test these theories more clearly, meditators would be an excellent comparison group, because meditation is more clearly cognitively-focused.

#### **4.4 Psychological factors**

After controlling for family-wise error, the data supported the prediction that both the yoga group and running group have lower scores on depression, trait anxiety, and hostility compared to the sedentary group. Only runners reported greater social support compared to sedentary individuals.

The finding that yoga practitioners reported fewer depressive symptoms compared to sedentary individuals is consistent with past studies that have shown reductions in depressive

symptoms after yoga intervention in depressed participants (see review by Pilkington et al., 2005) and in non-depressed participants (e.g., Rani & Rao, 2005). The finding that running was associated with fewer depressive symptoms is also consistent with past research on exercise intervention (see meta-analysis by Lawlor & Hopker, 2001). This study is the first to show that yoga practitioners and runners report equivalently low levels of depressive symptoms compared to sedentary individuals, and is consistent with the previous finding that aerobic and anaerobic exercise interventions had equivalent effects on depressive symptoms (North et al., 1990).

The present study is the first cross-sectional study to show lower trait anxiety in yoga practitioners compared to sedentary individuals, and it adds to the literature on yoga intervention and anxiety, which, though characterized by methodological difficulties, shows consistently positive effects (Kirkwood et al., 2005). The lower levels of anxiety in runners compared to sedentary individuals is not surprising given that many studies have examined the relationship between exercise and anxiety, and have shown favorable effects (Landers & Petruzzello, 1994). However, effects of exercise are generally shown directly after exercise, while this study showed that runners, who were explicitly asked to refrain from exercise for six hours prior to study participation, reported fewer anxiety symptoms. An intervention study would need to be conducted in order to conclude whether yoga and running or other aerobic exercise are truly equivalent in reducing anxiety, but the current findings suggest that yoga may be an excellent alternative exercise for individuals who cannot engage in high-impact exercise due to injury, frailty, or other medical conditions.

The present study is also the first cross-sectional study to show lower hostility in yoga practitioners compared to sedentary individuals, and joins the few studies that have examined this question and found that hostility is decreased by yoga intervention (Bhushan & Sinha, 2001;

Lavey et al., 2005). The mixed results that have been found for the effect of exercise on hostility suggest that exercise may offer stronger acute reductions in hostility compared to long-term reductions (Berger & Motl, 2000). While causality cannot be assumed in a cross-sectional study, the present study suggests that running and yoga may impact trait hostility in the longer term, as the participants were explicitly asked not to engage in exercise for six hours before study participation.

Little is known about the relationship between social support and yoga or running. Social support had not previously been studied cross-sectionally in yoga practitioners or after yoga intervention. Although not explicitly examining running, an association between physical activity level and social functioning has been previously demonstrated (Allison, 1990). It has been demonstrated through path analysis that social support can influence exercise adherence by augmenting perceived behavioural control and intention to exercise (Courneya & McAuley, 1995), thereby suggesting that greater social support may have promoted the uptake or maintenance of regular running in the present study sample. In the present study, the runners (65%) were almost twice as likely as the yogis (34%) to endorse social interaction as a goal of running, indicating that running may provide more social interaction than yoga practice (see Table 3). In order to understand if greater social support is a cause or effect of running activity, change in social support would need to be studied in intervention trials.

I predicted that the yoga group would report greater mindfulness compared to the running group and the sedentary group. Contrary to predictions, there were no group differences at the corrected alpha level, though the yoga group displayed greater mindfulness compared to the other groups at the  $p = .04$  level. It is plausible that including individuals with a longer history of yoga practice would have yielded stronger results, as greater mindfulness has been demonstrated by

comparing yogis who have practiced for more than five years with yogis who practiced for less than five years (Brisbon & Lowery, 2009). However, the mean mindfulness score ( $M = 4.62$ ,  $SD = .51$ ) of the experienced yogis in Brisbon and Lowery's (2009) study was exactly equal to the mean of the yoga group in the present study. Additionally, years of yoga practice did not correlate with mindfulness in Brisbon and Lowery's (2009) study or in the present study, though years of Zen meditation practice has been shown to correlate with mindfulness measured by the MAAS (Brown & Ryan, 2003).

The present study confirmed the scale developers' findings that trait mindfulness, measured by the MAAS, is correlated with a range of mental health constructs (Brown & Ryan, 2003). These replications included medium to high negative correlations between mindfulness and depression, anxiety, perceived stress and hostility, using Cohen's effect size descriptions (Cohen, 1992). The present study was the first to examine and to demonstrate a small positive correlation between mindfulness and social support.

#### **4.5 Lifestyle factors**

Contrary to predictions, the yoga group only reported significantly healthier lifestyle choices compared to sedentary individuals related to cigarette smoking and vegetarianism. Runners, however, reported a lower incidence of being a cigarette smoker, better sleep, and lower caffeine consumption compared to sedentary individuals, and higher alcohol consumption compared to sedentary individuals and yogis. There were no group differences on marijuana use.

Vegetarian diets are associated with lower blood pressure, reduced incidence of hypertension, and lower risk of death from ischemic heart disease (Craig & Mangels, 2009). The present study found that yogis, but not runners, are more likely to be vegetarian than sedentary



individuals. Because the runners generally endorsed healthier lifestyle choices relative to sedentary individuals, but not specifically vegetarian diet, the difference in diet in the yoga group may be attributed to the yogic value of non-harming as opposed to, or in addition to, the value of health. Given the higher incidence in yoga practitioners, vegetarianism should be controlled in cross-sectional studies that examine the health of yoga practitioners. Additionally, yoga interventions that include vegetarian diets present the difficulty of needing to tease apart cardiovascular benefits from diet and aspects of yoga practice such as asana, and should therefore also assign a vegetarian diet in the control group or not at all.

Smoking has been linked with cardiovascular risk including increased blood pressure (Hatsukami et al., 2005) and increased ten-year risk of death from cardiovascular disease (Conroy et al, 2003). Consistent with predictions, yogis and runners had lower incidences of smoking compared to the sedentary individuals. The association between group membership and smoking status may be due to a greater commitment to health in the activity groups compared to the sedentary group. It may be causal given that exercise has been shown to decrease cravings and withdrawal symptoms in individuals in the process of quitting smoking (Taylor, Ussher, & Faulkner, 2007) and given the limited evidence that individuals who engage in mind-body therapies including yoga are more likely to be successful at quitting smoking (Gillum, Santibañez, Bennett, & Donahue, 2009). Finally, it may be that cigarette smokers are less likely to engage in yoga or running due to greater difficulty exercising. This position is supported by the finding that individuals tend to increase exercising after quitting smoking and to decrease exercising after relapsing (Nagaya, Yoshida, Takahashi, & Kawai, 2007). Irrespective of the explanation, attention to smoking status should be paid in cross-sectional and intervention studies of yoga and exercise groups.

The finding that yoga practitioners did not have better sleep is inconsistent with another cross-sectional study that demonstrated better sleep in Spanish yoga practitioners compared to controls (Vera et al., 2009). A possible explanation for the discrepancy is that the Spanish sample practiced yoga for at least three years, while the present study's sample practiced for at least two years. There also appear to be differences in sleep quality between the total sample in Vera et al.'s study and in the present study, in that both of Vera et al.'s groups, but none of the groups in the present study, could be categorized as "good" sleepers. The finding that runners reported better sleep compared to sedentary individuals is consistent with past research showing that exercise improves sleep. More physically active individuals have reported greater sleep duration and have displayed better sleep architecture including increase Stage 2 sleep (Youngstedt, O'Connor, & Dishman, 1997). The American Sleep Disorders Association considers physical exercise to be a treatment for sleep disorders, though methodological differences among studies prohibit the determination of the most appropriate duration, intensity, type and timing of exercise in order to improve sleep (Driver & Taylor, 2000). The present study provides a clue that aerobic exercise may be more beneficial than non-aerobic exercise, however the running and yoga groups did not differ in the present study, and causality cannot be inferred. Better sleepers may, after all, be more likely to exercise.

Caffeine does not appear to influence cardiovascular health when consumed moderately (less than four cups of coffee per day) and has not been clearly shown to influence cardiovascular health when consumed in high quantities, though caffeine has been shown to increase BP acutely (Nawrot et al., 2003), and was therefore prohibited before study participation. Caffeine was therefore examined in this study to understand lifestyle choices in the activity groups, rather than as a mediator between running participation and physiological outcomes. Because caffeine and

sleep have a bi-directional relationship (Roehrs & Roth, 2008), it is unclear whether the runners' lower caffeine consumption relative to the other groups is the cause or result of their superior sleep compared to the sedentary group.

The finding that runners consumed greater amounts of alcohol compared to the other groups should not be misinterpreted as evidence that the runners had problematic drinking habits. In the present study, the higher alcohol consumption was relative to the rest of the sample, and the measure used in this study (DUF) does not allow for a precise quantification of alcohol consumption. However, examination of individual questions regarding alcohol consumption showed that the average runner reported consuming alcohol less than three times per month, and consuming one to three drinks each occasion. Therefore, although this difference is statistically significant, the runners reported drinking modestly. Given that light to moderate alcohol consumption, defined as one daily alcoholic beverage in females and one to two in males, is actually considered protective for cardiovascular health (O'Keefe, Bybee, & Lavie, 2007), the runners may even benefit from their level of alcohol consumption.

#### **4.6 Waist circumference**

Contrary to predictions, neither the yoga group nor the running group had significantly smaller waist circumferences compared to the sedentary group. To put the waist circumference values in context, the suggested cut-off scores for waist circumference that are associated with cardiovascular risk are greater than or equal to 80 cm for females, and 90 cm for males (Dobbelsteyn et al., 2001). The mean waist circumference for both sedentary females and males were below the respective cut-off scores, with sedentary females at 75.73 ( $SD = 8.5$ ) and males at 86.41 ( $SD = 12.17$ ), suggesting there may have been a floor effect in this study. These findings

do not preclude that the uptake of yoga could reduce waist circumference in individuals who have larger than recommended waist circumferences, as has been previously demonstrated in an overweight or obese sample (e.g., Littman et al., 2011).

#### **4.7 Personality**

Because personality is relatively stable, examining group differences on the Big-five personality dimensions offers a glimpse, albeit a cloudy one, into whether personality factors may have preceded and influenced the differential uptake of yoga or running practice. The only group difference in personality was that runners scored significantly higher than sedentary individuals on conscientiousness. Conscientiousness has been previously linked with healthy behaviours, which in turn lead to greater longevity (Martin, 2007). The examination of personality offers some insight into whether individuals of different personality types may have chosen different practices to tackle the inherent limitation of the cross-sectional design of this study. However, although personality tends to be consistent over time in adults, it could also be changed by experience such as extensive participation in running or yoga, and consistency does not peak until after age 50 (Roberts & DelVecchio, 2000). This finding that yogis and sedentary individuals did not differ on any personality dimension, in addition to the finding that SES did not differ between groups, offers some indication that the differences between groups may be attributed to yoga practice itself, though causality still cannot be determined.

#### **4.8 Limitations**

The most serious limitation of this study applies to cross-sectional research in general. This study lacks the control of a randomized controlled trial, and is limited by participants' individual differences that lead to the uptake and maintenance of regular yoga or running. The equivalence

in personality, with the exception of greater conscientiousness in the running group compared to others, provides some indication that observed group differences can be attributed to yoga practice, but it by no means allows for the causal interpretation of results. It is therefore difficult to use the study results to predict the effectiveness of a yoga intervention in improving cardiovascular outcomes. On the one hand, the frequency and length of history of yoga and running practice in this cross-sectional study is greater than could be expected from participants in a randomized controlled trial assigned to yoga and running practice, and group differences could therefore be viewed as maximal. On the other hand, participants in this study are healthy and results may therefore be constrained by ceiling and floor effects. For example, yoga intervention may lower blood pressure in individuals with hypertension or reduce depressive symptoms in individuals with depression, while no group differences are found between yoga practitioners and sedentary individuals. Conclusions in the present study can only be made about healthy individuals without cardiovascular disease between the ages of 20 and 59 living in Vancouver.

Another limitation of the present study is that the yoga group was comprised of different styles of Hatha yoga. Because there was no precedent for recruiting regular yogis in Vancouver, it was difficult to foresee the rates of acquiring participants, and in hindsight, it would not have been feasible to recruit an adequate sample size within a reasonable length of time if inclusion criteria had been restricted to one type of Hatha yoga. Therefore, conclusions are made about the average regular practitioner of Hatha yoga (including asana). Given the findings that aerobic fitness mediated outcomes of interest in the present study, it is possible that different styles of yoga, differing in aerobic intensity, have different effects on cardiovascular health, and it would

therefore be helpful if future work would either restrict yoga style or be adequately powered to test for differences between styles.

Another limitation is that the laboratory stressors used in the present study did not yield large self-reported changes in anxiety symptoms though cardiovascular reactivity was sufficient for hypothesis testing. This prohibited the adequate testing of the relationship between trait and state anxiety as well as the testing of whether or not yoga practitioners and runners differed in self-reported anxiety symptoms in response to the somatic task versus the cognitive task. Future research will be enriched by the use of stressors that provoke stronger subjective anxiety responses than in the present study.

It appears that the sedentary group in the present study was healthier than anticipated, and this attenuated the ability to find group differences on variables such as blood pressure and waist circumference. To put this in context, it should be noted that residents of British Columbia have been shown to have the healthiest lifestyles of all Canadian provinces, on factors such as physical activity, cigarette smoking, obesity, and binge drinking (Canadian Community Health Survey, 2010). Therefore, group differences between regularly practicing yoga practitioners or runners and individuals who report sedentary lifestyles may be larger outside British Columbia.

Finally, the measure of socioeconomic status, the Hollingshead Four Factor measure of Social Status (1975), was incorrectly administered by failing to assess levels of spousal educational and employment. Due to this error, the study only yielded parental SES, which was appropriate for students, but was not ideal for non-students. While parental SES does predict adult SES (e.g., Corcoran, 1995), one cannot be assured that the groups in the present study had equivalent SES, though they had equivalent parental SES.

#### **4.9 Study contributions and recommendations for future research**

The present study was the first cross-sectional study to show that individuals who regularly practice yoga have resting HR and HRV values that are comparable to regular runners, and superior to sedentary individuals. It was one of the only studies to date to have measured HRV at rest as opposed to directly after yoga practice. Given that resting HR and HRV are associated with positive cardiovascular health outcomes, it is promising that individuals who may be unable to engage in a high-impact practice like running may be able to reap cardiovascular benefits from yoga, though causality cannot be assumed in this study. Because the group difference in resting HR and HRV between yogis and sedentary individuals was mediated by aerobic fitness, it will be important for future studies to determine if low intensity yoga styles, which are less likely to improve aerobic fitness, are also associated with cardiovascular benefits.

A strength of the present study was its attention to age and race/ethnicity, which strengthened the validity of findings of group differences, but also lead to an important incidental finding that Asian adults have lower HF power compared to White adults, which had not been previously examined. Future research is needed to replicate this finding, to understand why this difference exists, and to appreciate the implications for the cardiovascular health of Asian Canadians.

Respiration rate was the only physiological variable in this study on which the yoga group showed an advantage over the running group, and this was especially true for the yoga practitioners who regularly practiced the Ujjayi breathing technique. Respiration indices and techniques are therefore important aspects of yoga that should be explicitly reported and examined in future yoga research.

The absence of resting BP differences in this study may be due to problems with our sample (e.g., age restriction, exclusion of hypertensive individual, possibly excessive physical activity in the sedentary group), and improvement in BP due to yoga and running could certainly still be found in randomized controlled trials. The finding does caution researchers not to take it for granted that physically active groups will show superior BP compared to sedentary groups cross-sectionally. Contrary to predictions, runners and female yoginis displayed greater BP reactivity compared to sedentary individuals averaged across tasks, and, contrary to prediction, female yoginis also showed poorer recovery. These findings do not prohibit the possibility that yoga intervention could decrease sympathetic activation in response to stress, but there is no evidence from the present study suggesting that it would. To help resolve discrepant findings, future research of the relationship between yoga or physical activity and cardiovascular reactivity should examine different stressors (e.g., social versus asocial) and always include gender as a moderator.

Lifestyle factors proved to be important in this study, though lifestyle is often ignored in the yoga literature. It was impossible in the present study to establish whether yoga or running practice was the cause or effect of lifestyle practices, or whether they are linked by other factors such as conscientiousness or the commitment to health. Only randomized controlled trials will be able to disentangle these variables from yoga and exercise practices themselves. Waist circumference was the only hypothesized mediator in the present study to not be significantly different between groups. An intervention study, especially one that includes overweight individuals, may still find that yoga could reduce waist circumference, and it remains a potentially important and understudied factor to consider in the yoga literature.



Psychological factors including depression, perceived stress, trait somatic anxiety, trait cognitive anxiety, hostility and social support were no different between yogis and runners, though both groups fared better than sedentary individuals. Even differences in mindfulness did not reach statistical significance. It is encouraging that individuals may be able to reap psychological benefits from yoga practice that are equivalent to the benefits from more aerobically intense exercise which may not be accessible for some individuals. It also must be acknowledged that the psychological variables examined in this study were chosen due to their association with cardiovascular health, and by no means represent all aspects of human experience that could be influenced by yoga practice. For example, improvements on positive psychological variables such as spiritual well-being and quality of life have been demonstrated (Duncan, Leis, Taylor-Brown, 2008). This is a potentially fruitful area of research and high quality randomized controlled trials that examine the effects of yoga practice on positive psychological variables compared to both a physical activity group and a passive control group are lacking.

The hypothesized model of how yoga could affect cardiovascular health (Figure 1) was effective in organizing hypotheses, results, and needs for future research. In the present study, the mediational pathways that were demonstrated linked yoga practitioners to superior aerobic fitness to lower HR and higher HRV, as well as lower respiration rate to higher HRV compared to sedentary individuals. Though these were the only mediational findings, the yogis differed from sedentary individuals on psychological factors and lifestyle factors in addition to aerobic fitness and respiration rate. In light of the present study's findings, it is still possible that these factors could explain how yoga could influence resting BP, HR, and HRV in an intervention study, and it remains an open question whether or not these factors could influence different markers of

cardiovascular health such as cholesterol or whether they could influence more distal cardiovascular outcomes such as coronary heart disease. The field would also be advanced by elaborating on the type of model used in the present study both in terms of broader psychological variables that effect psychological and physiological changes like self-esteem, and in terms of physiological pathways such as neurological, endocrinological, and immunological mechanisms. Kiecolt-Glaser et al. (2010) have recently pioneered this work by measuring IL-6 and C-reactive protein in order to explain cardiovascular reactivity and psychological variables in yoga practitioners.

The present study demonstrated that yogis and runners differ from sedentary individuals on various contributors to cardiovascular health. There was little specificity in this study showing that yoga can influence physiological or psychological contributors to cardiovascular health more strongly or differently compared to other physical exercise, with the exception of respiration rate and vegetarianism. For this reason, it is evident that the quality of research on the effectiveness of yoga would be much improved by including a physical activity group in addition to a sedentary or passive control group, in order to make specific claims about the effects of yoga. Although yoga did not emerge as superior to running or unique in its association with cardiovascular health, it would be remarkable if future evidence emerges that individuals can reap similar benefits from yoga as from the high-intensity practice of running. Individuals who lack the capability or willingness to engage in high-intensity physical exercise have much to gain from the continuation of this line of research. It is clear that future research is needed to better understand both the effect of yoga on cardiovascular health and its mechanisms. Important future contributions lie in the comparison of Hatha yoga practice to other physical practices, including

metabolically-matched physical activities like walking, and in using the approach of the present study to understand how yoga could affect cardiovascular health.

## Tables

Table 1. Descriptive demographic information

Demographic variables	Total (n = 145)	Yoga (n = 47)	Running (n = 46)	Sedentary (n = 52)	Significant group differences
Age ( <i>M, SD</i> )	35.86 (11.45)	39.51 (11.02)	33.59 (9.8)	34.58 (12.55)	Yoga > Running*
Gender (Female %)	56	57	57	54	None
<b>Race/ethnicity (% of group)</b>					
Asian/South Asian	28	13	26	44	Yoga < Sedentary**
Caucasian/White	61	78	67	50	Yoga > Sedentary**
African/Black	2	0	7	0	Not examined
First Nations	3	4	0	4	Not examined
Hispanic	1	2	0	2	Not examined
Middle Eastern	1	2	0	0	Not examined
<b>Religion (% of group)</b>					
Non-religious	51	43	63	48	None
Buddhism	11	21	4	8	Yoga > Running*
Christianity	26	11	28	38	Sedentary > Yoga**
Hinduism	2	6	0	0	Not examined
Islam	1	2	0	2	Not examined
Judaism	2	2	4	0	Not examined
Baha'i	1	2	0	2	Not examined
Shamanism	1	2	0	0	Not examined
"Spiritual"	3	6	0	2	Not examined
Mixed	1	4	0	0	Not examined
Marital status (% partnered)	44	36	59	37	Running > Sedentary*, Running > Yoga*
Student (% of group)	31	19	33	40	None
SES, parental ( <i>M, SD</i> )	45.68 (14.17)	46.13 (10.9)	49.07 (14.65)	42.1 (15.71)	None

\* $p \leq .05$ , \*\* $p \leq .01$ , †  $p \leq .001$

Table 2. Descriptive statistics of yoga group

Yoga descriptive (n = 47)	Mean, Standard Deviation	Range (Minimum-Maximum)
Years of yoga	6.49 (3.67)	2.0-18.0
Yoga times per week	5.1 (4.12)	2.5-30
Yoga minutes per week	277.45 (153.97)	90-840
Meditation minutes per week	127.21 (215.51)	0-1260
Breathing exercise times per week	6.9 (18.73)	0-125
Yoga instructor?	49 %	
Practice Ujjayi breath?	70 %	
Yogic philosophy part of daily life?	87 %	
Yoga style (%)		
“Hatha”	20	
Ashtanga	15	
Power	15	
Yin	11	
Mixed	9	
Flow/ Vinyasa flow	6	
Iyengar	6	
Kundalini	6	
“Meditative”	2	
Pranayam	2	
Restorative	2	
“Sun salutation”	2	
Don’t know	2	

Table 3. Goals of yoga and running practice

	Cardiovascular health	Overall health	Improve appearance	Improve mood	Decrease tension	Challenge/ accomplishment	Social interaction	Connect with higher power	Self-realization	Other
<b>Goal (% endorsed)</b>										
<b>Yoga group</b>										
Total	43	96	60	87	83	45	34	57	77	43
Male	60	95	70	90	85	50	55	75	90	35
Female	30	96	52	85	81	41	20	44	67	48
<b>Running group</b>										
Total	63	100	80	78	43	83	65	13	46	11
Male	70	100	75	70	45	85	65	25	50	15
Female	58	100	85	85	42	81	65	2	42	25
<b>Most important (% endorsed)</b>										
<b>Yoga group</b>										
Total	0	40	0	17	4	0	0	6	13	15
Male	0	35	0	15	0	0	0	10	20	10
Female	0	44	0	19	7	0	0	4	7	19
<b>Running group</b>										
Total	0	46	11	13	2	17	4	0	2	4
Male	0	55	0	5	5	20	5	0	5	5
Female	0	38	19	19	0	15	4	0	0	4

Table 4. Descriptive statistics of running group

<b>Running descriptives (n = 46)</b>	<b><i>M (SD)</i></b>	<b>Range (Minimum-Maximum)</b>
<b>Years of running</b>	8.3 (6.99)	2.0-43.0
<b>Times per week</b>	3.96 (1.18)	2.5-8.0
<b>Minutes per week</b>	218.8 (116.4)	90-600
<b>Marathon in last 2 years? (%)</b>	30	
<b>Half-marathon in last 2 years? (%)</b>	50	
<b>Was goal competitive? (%)</b>	22	

Table 5. Baseline physiological, psychological, personality, and aerobic fitness descriptive statistics

	<b>Total (M, SD)</b>	<b>Yoga (M, SD)</b>	<b>Running (M, SD)</b>	<b>Sedentary (M, SD)</b>	<b>Significant group differences</b>
<b>Physiological</b>					
SBP	106.91 (11.69)	106.88 (11.61)	108.7 (12.12)	105.38 (11.39)	None
DBP	71.55 (8.61)	72.25 (8.34)	71.87 (9.01)	67.03 (11.8)	None
HR	61.43 (10.71)	60.23 (8.08)	56.18 (9.58)	70.66 (8.59)	Yoga < Sedentary*, Running < Sedentary†
Respiration rate	13.35 (2.34)	12.44 (2.5)	13.43 (2.35)	14.07 (2.0)	Yoga < Sedentary**
lnHF	5.94 (1.2)	6.29 (1.13)	6.3 (1.0)	5.38 (1.21)	Yoga > Sedentary*, Running > Sedentary*
Waist circumference	80.44 (11.54)	81.2 (8.58)	77.64 (7.88)	82.23 (15.62)	None
Aerobic fitness zone	2.09 (1.13)	2.04 (1.19)	1.44 (0.79)	2.7 (1.02)	Yoga > Sedentary**, Running > Sedentary†, Running > Yoga*
<b>Psychological</b>					
Depression	6.58 (6.6)	4.98 (5.23)	4.73 (5.26)	9.64 (7.68)	Yoga < Sedentary†, Running < Sedentary†
Perceived Stress	13.41 (7.27)	11.02 (6.11)	11.84 (6.94)	16.94 (7.23)	Not examined
Trait Anxiety	32.12 (8.01)	30.07 (5.31)	29.45 (6.98)	36.3 (9.18)	Yoga < Sedentary†, Running < Sedentary†
Somatic trait anxiety	15.18 (3.52)	14.51 (2.41)	14.09 (2.94)	16.74 (4.27)	Yoga < Sedentary**, Running < Sedentary†
Cognitive trait anxiety	16.94 (5.55)	15.56 (3.92)	15.36 (4.86)	19.56 (6.42)	Yoga < Sedentary†, Running < Sedentary†
Hostility	17.24 (6.11)	15.69 (5.51)	16.2 (5.73)	19.54 (6.35)	Yoga < Sedentary**, Running < Sedentary**
Social Support	39.86 (6.49)	40.07 (6.39)	42.55 (3.7)	37.1 (7.84)	Running < Sedentary†
Mindfulness	4.34 (0.81)	4.62 (0.73)	4.18 (0.93)	4.23 (0.73)	None
<b>Personality</b>					
Extraversion	8.47 (3.28)	8.43 (2.7)	9.13 (3.65)	7.92 (3.37)	None
Agreeableness	10.5 (2.5)	11.09 (2.24)	10.65 (2.51)	9.83 (2.55)	None
Openness to experience	11.32 (2.23)	12.11 (1.7)	11.12 (2.28)	10.56 (2.39)	None
Conscientiousness	11.08 (2.63)	11.6 (2.2)	11.8 (2.32)	9.98 (2.91)	Running > Sedentary†
Emotional Stability	13.99 (1.74)	14.6 (1.61)	13.96 (1.69)	13.48 (1.75)	None

\* $p \leq .05$ , \*\* $p \leq .01$ , † $p \leq .001$



Table 6. Correlations between resting physiological variables

	<b>Systolic blood pressure (SBP)</b>	<b>Diastolic blood pressure (DBP)</b>	<b>Heart rate (HR)</b>	<b>Respiration rate (RR)</b>
<b>SBP</b>	1 n = 143			
<b>DBP</b>	.87† n = 143	1 n = 143		
<b>HR</b>	-.01 n = 143	.06 n = 143	1 n = 143	
<b>RR</b>	.02 n = 139	.02 n = 139	.05 n = 139	1 n = 139
<b>lnHF</b>	-.11 n = 136	-.1 n = 136	-.37† n = 136	-.33† n = 135

†  $p \leq .001$

Table 7. Correlations between psychological variables

	<b>Depression</b>	<b>Total anxiety</b>	<b>Somatic anxiety</b>	<b>Cognitive anxiety</b>	<b>Perceived stress</b>	<b>Hostility</b>	<b>Social support</b>
<b>Depression</b>	1 n = 145						
<b>Total anxiety</b>	.74† n = 141	1 n = 141					
<b>Somatic anxiety</b>	.5† n = 142	.81† n = 141	1 n = 142				
<b>Cognitive anxiety</b>	.74† n = 144	.93† n = 141	.54† n = 141	1 n = 144			
<b>Perceived stress</b>	.77† n = 143	.7† n = 140	.41† n = 141	.74† n = 142	1 n = 143		
<b>Hostility</b>	.48† n = 145	.49† n = 141	.25** n = 142	.55† n = 144	.54† n = 143	1 n = 145	
<b>Social support</b>	-.45† n = 144	-.39† n = 140	-.2* n = 141	-.45† n = 143	-.41† n = 142	-.48† n = 144	1 n = 144
<b>Mindfulness</b>	-.45† n = 144	-.49† n = 140	-.28† n = 141	-.52† n = 143	-.56† n = 143	-.47† n = 144	.23** n = 144

\* $p \leq .05$ , \*\* $p \leq .01$ , †  $p \leq .001$

Table 8. Correlations between personality variables

	<b>Extraversion (E)</b>	<b>Agreeableness (A)</b>	<b>Conscientiousness (C)</b>	<b>Emotional stability (ES)</b>
<b>E</b>	1 n = 145			
<b>A</b>	.09 n = 145	1 n = 145		
<b>C</b>	.05 n = 145	.16 n = 145	1 n = 145	
<b>ES</b>	.06 n = 145	.24** n = 145	.3†. n = 145	1 n = 145
<b>OE</b>	.27** n = 145	.32† n = 145	-.03 n = 145	.23** n = 145

\*\* $p \leq .01$ , †  $p \leq .001$

Table 9. Lifestyle descriptive statistics, by group

	<b>Total</b>	<b>Yoga</b>	<b>Running</b>	<b>Sedentary</b>	<b>Significant group differences</b>
<b>Global Sleep</b>	8.08 (3.11)	7.82 (2.3)	7.2 (3.15)	9.08 (3.45)	Runners < Sedentary†
<b>Cigarette Smoker (%)</b>	13	2	2	33	Sedentary > Yoga**, Sedentary > Running†
<b>Marijuana use</b>					
Never/3 months	76	70	83	75	None
1-2/3 months	14	15	11	15	None
Several/1 month	5	6	7	2	None
Several/week	3	6	0	2	None
Daily	3	2	0	6	None
<b>Diet</b>					
Meat-eating (meals per week)	7.01 (5.47)	4.07 (4.75)	7.23 (4.84)	9.41 (5.43)	Not examined
Vegan (%)	3	9	2	0	Not examined
Lacto-ovo vegetarian (%)	6	15	2	2	Not examined
Semi-vegetarian (%)	8	15	7	4	Not examined
Non-vegetarian (%)	82	62	89	94	Yoga > Sedentary†, Yoga > Running*
<b>Caffeine</b>					
0 cups (%)	26	23	20	35	None
1-2 cups (%)	44	45	61	29	See text
3+ cups (%)	32	32	20	37	See text
<b>Alcohol</b>					
Lowest tertile (%)	30	38	9	42	See text
Middle tertile (%)	38	34	37	42	See text
Highest tertile (%)	32	28	54	15	See text

Table 10. Cardiovascular changes in response to laboratory stressors

	<b>Total</b>	<b>Yoga</b>	<b>Running</b>	<b>Sedentary</b>
<b>Cardiovascular change averaged across tasks</b>				
<b>SBP change</b>	7.87 (5.31)	7.86 (5.48)	9.52 (5.5)	6.54 (4.68)
<b>DBP change</b>	6.62 (4.02)	6.77 (4.37)	7.68 (4.21)	5.63 (3.28)
<b>HR change</b>	4.75 (3.77)	4.81 (3.94)	5.82 (3.45)	3.81 (3.7)
<b>Cardiovascular change in response to the arithmetic task</b>				
<b>SBP change</b>	7.7 (6.68)	8.07 (7.61)	9.07 (9.92)	6.25 (5.37)
<b>DBP change</b>	6.51 (5.12)	6.71 (5.84)	6.67 (5.36)	6.19 (4.22)
<b>HR change</b>	6.93 (5.34)	6.77 (5.76)	7.8 (5.0)	6.38 (5.22)
<b>Cardiovascular change in response to the handgrip task</b>				
<b>SBP change</b>	8.08 (7.61)	7.84 (6.85)	9.92 (8.58)	6.81 (7.31)
<b>DBP change</b>	6.69 (5.8)	6.63 (6.06)	8.75 (5.86)	5.07 (5.05)
<b>HR change</b>	2.6 (4.11)	2.83 (4.13)	3.91 (4.11)	1.32 (3.78)

Table 11. Changes in state anxiety in response to stressors, by group (with outliers removed)

	<b>Total</b>	<b>Yoga</b>	<b>Running</b>	<b>Sedentary</b>
<b>State anxiety change averaged across tasks</b>				
<b>Cognitive anxiety change</b>	0.21 (1.18)	0.47 (1.13)	-0.19 (1.08)	0.15 (1.15)
<b>Somatic anxiety change</b>	1.87 (1.74)	1.69 (1.79)	2.2 (1.53)	1.75 (1.86)
<b>State anxiety change in response to the arithmetic task</b>				
<b>Total anxiety change</b>	2.12 (2.93)	2.46 (3.59)	2.57 (2.28)	1.4 (2.63)
<b>Cognitive anxiety change</b>	0.59 (1.7)	0.79 (1.88)	0.91 (1.76)	0.1 (1.37)
<b>Somatic anxiety change</b>	1.48 (2.06)	1.56 (2.31)	1.66 (1.66)	1.25 (2.13)
<b>State anxiety change in response to the handgrip task</b>				
<b>Total anxiety change</b>	1.96 (2.77)	1.42 (2.56)	2.77 (2.6)	1.78 (3.02)
<b>Cognitive anxiety change</b>	-0.29 (1.28)	-0.38 (1.37)	0.03 (0.92)	-0.48 (1.43)
<b>Somatic anxiety change</b>	2.25 (2.34)	1.81 (2.17)	2.74 (2.23)	2.25 (2.56)

Table 12. Differences in SBP, DBP, HR between recovery at minute 2 and baseline (excluding multivariate outliers)

	<b>Total</b>	<b>Yoga total</b>	<b>Yoga males</b>	<b>Yoga females</b>	<b>Running total</b>	<b>Running males</b>	<b>Running females</b>	<b>Sedentary total</b>	<b>Sedentary males</b>	<b>Sedentary females</b>
<b>Recovery in response to the arithmetic task</b>										
<b>SBP (M, SD)</b>	1.5 (5.41)	2.01 (5.96)	-0.1 (5.47)	4.23 (6.38)	2.39 (5.28)	3.76 (5.59)	1.34 (4.89)	0.26 (4.85)	0.11 (4.92)	0.39 (4.88)
<b>DBP</b>	0.86 (4.03)	0.46 (3.9)	-0.83 (3.86)	1.54 (3.62)	1.28 (3.88)	2.18 (4.12)	0.6 (3.61)	0.85 (4.31)	1.93 (3.94)	-0.07 (4.47)
<b>HR</b>	2.69 (4.02)	2.41 (3.9)	3.53 (3.67)	1.56 (3.93)	2.77 (4.29)	3.05 (3.05)	2.56 (5.08)	2.86 (3.96)	2.38 (4.45)	3.3 (3.51)
<b>Recovery in response to the handgrip task</b>										
<b>SBP</b>	0.26 (5.65)	0.73 (4.63)	0.18 (4.11)	1.18 (5.05)	0.18 (6.26)	1.58 (7.08)	-0.79 (5.37)	-0.09 (6.0)	1.48 (7.76)	-1.7 (3.18)
<b>DBP</b>	0.37 (3.88)	0.41 (3.84)	-0.65 (3.83)	1.26 (3.7)	0.33 (4.39)	0.58 (4.11)	0.12 (4.57)	0.36 (3.5)	0.98 (3.74)	-0.29 (3.28)
<b>HR</b>	1.64 (3.76)	1.75 (3.66)	1.4 (4.21)	2.08 (3.28)	2.14 (4.16)	2.26 (2.95)	2.0 (4.85)	1.12 (3.48)	1.13 (4.55)	1.2 (2.22)
<b>Recovery averaged across tasks</b>										
<b>SBP</b>	0.88 (4.25)	1.37 (4.17)	0.04 (3.93)	2.57 (4.09)	1.28 (4.17)	2.67 (4.1)	0.23 (3.99)	0.09 (4.36)	1.16 (4.64)	-0.72 (3.95)
<b>DBP</b>	0.66 (3.17)	0.49 (3.3)	-0.51 (3.11)	1.00 (3.57)	0.91 (3.32)	1.54 (3.81)	0.44 (2.9)	0.58 (2.94)	1.27 (3.26)	-0.01 (2.55)
<b>HR</b>	2.16 (3.07)	2.08 (2.9)	2.46 (3.16)	1.79 (2.71)	2.45 (3.3)	2.66 (2.28)	2.3 (3.95)	1.99 (3.05)	1.75 (3.9)	2.2 (2.08)

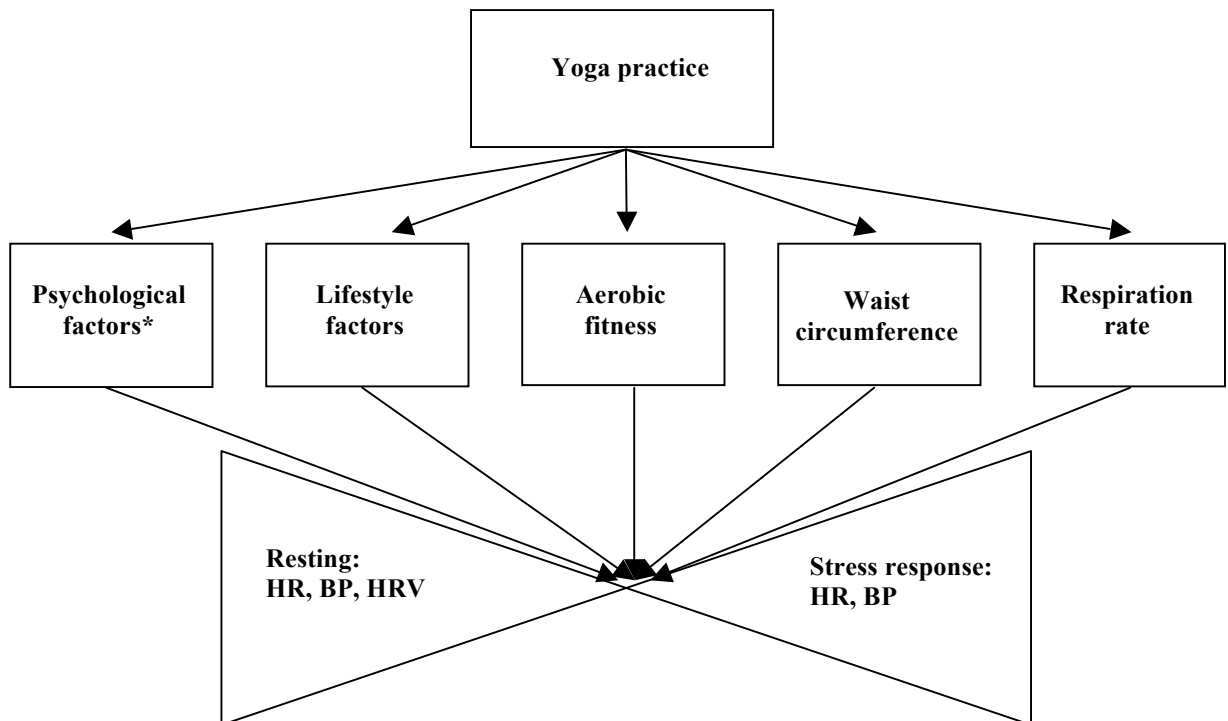
Table 13. Beliefs about yoga's effects on cardiovascular disease and cancer

	<b>Total</b>	<b>Yoga</b>	<b>Running</b>	<b>Sedentary</b>
<b>Beliefs about yoga's effects on cardiovascular disease</b>				
<b>No effect (%)</b>	17	13	22	19
<b>Prevent (%)</b>	50	60	46	40
<b>Improve (%)</b>	63	68	61	60
<b>Cure (%)</b>	12	29	9	8
<b>Beliefs about yoga's effects on cancer</b>				
<b>No effect (%)</b>	57	30	65	75
<b>Prevent (%)</b>	26	47	20	13
<b>Improve (%)</b>	33	57	8	19
<b>Cure (%)</b>	8	17	4	2



## Figures

Figure 1. Hypothesized model of the impact of yoga on physiological markers of cardiovascular health



\* Psychological factors refer to depression, anxiety, perceived stress, social support, hostility

Figure 2. Flow chart of exclusion and inclusion of study participants

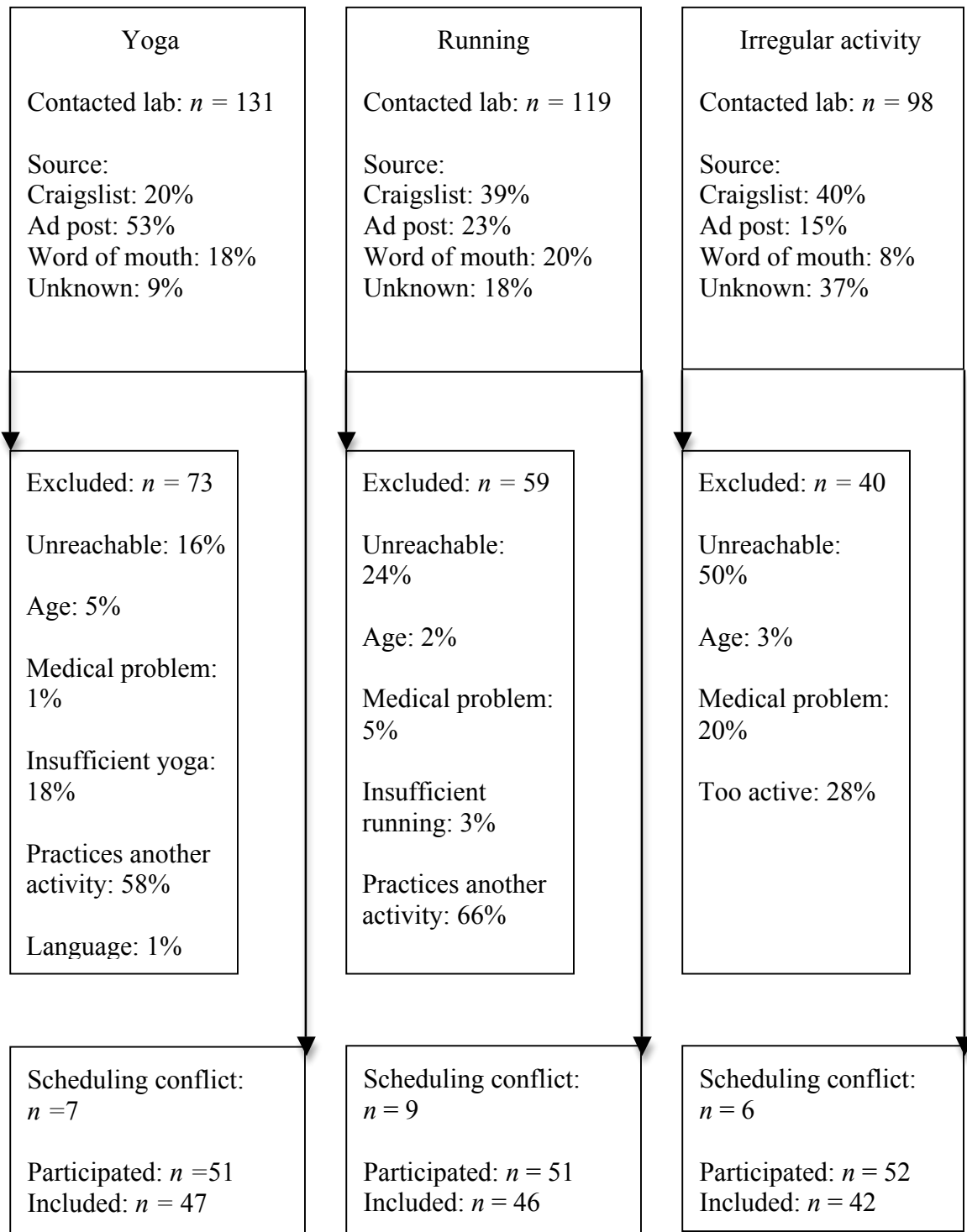


Figure 3. Group by gender interaction on SBP reactivity averaged across tasks

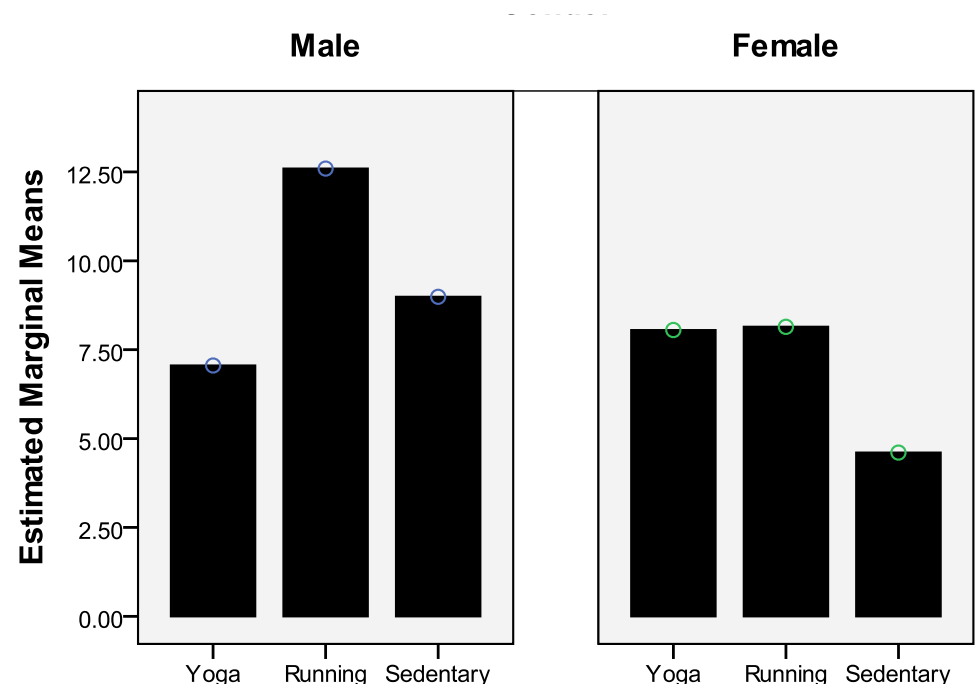


Figure 4. Group by gender interaction for SBP recovery averaged across both tasks

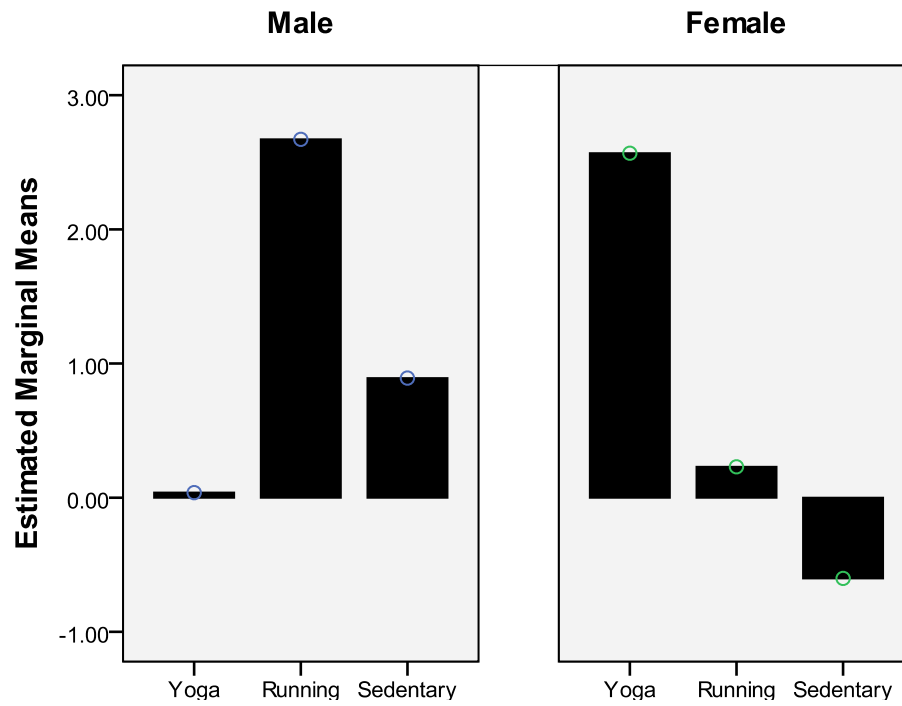
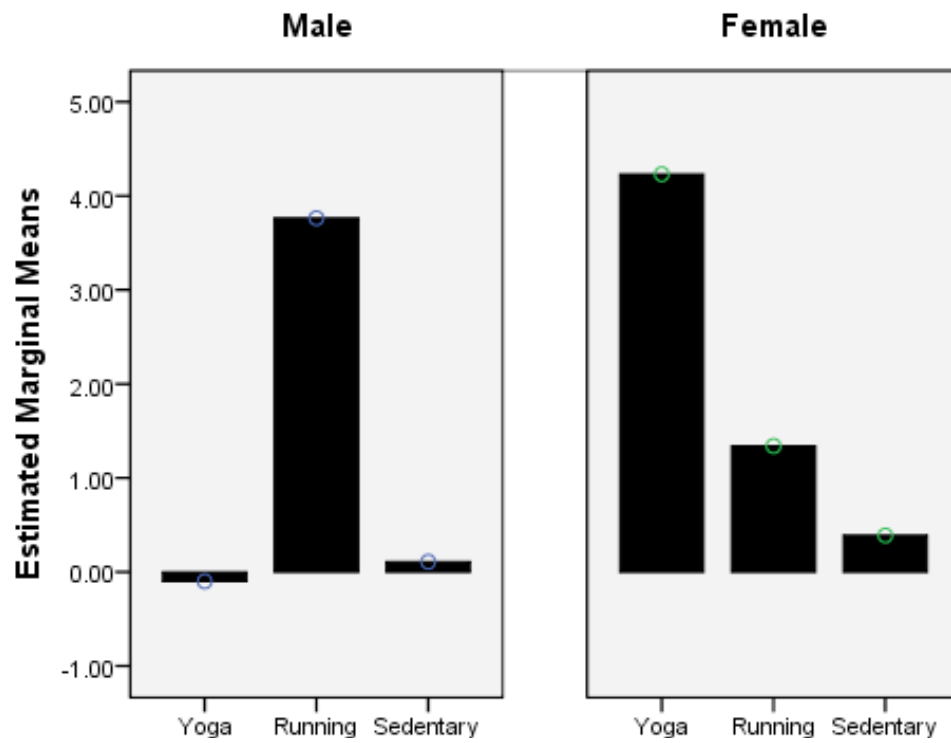


Figure 5. Group by gender interaction for SBP recovery in response to the arithmetic task



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## Appendix

### Appendix A: Participant recruitment advertisement



Participants needed for new study on mental and physical health

Do any of these groups describe you?

- 1) INDIVIDUALS WHO REGULARLY PRACTICE YOGA (3x/week, 2 years+)
- 2) INDIVIDUALS WHO REGULARLY RUN (3x/week, 2 years+)
- 3) INDIVIDUALS WHO DO NOT REGULARLY PRACTICE ANY ACTIVITY INTENDED TO REDUCE STRESS OR INCREASE FITNESS

If so, we would like to include you in a study of psychological and physiological contributors to cardiovascular health. It involves visiting the Behavioural Cardiology lab one time for 2.5 hours. You will be asked to complete questionnaires, laboratory experiments, and cardiovascular fitness testing. The study will be used for a Ph.D. thesis. Participants will receive financial compensation in appreciation.

To participate in our study, please contact via email at

Investigators: Dr. Wolfgang Linden and Jillian Satin, M. A., RYT